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24 May, 1882.

REPORT

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ON

AN EXAMINATION

OF THE

EXTERNAL AIR OF WASHINGTON.

BY

J. H. KIDDER, M. D.,
SURGEON, U. S. NAVY.

A.B. Class of '62

[EXTRACTED FROM THE REPORT OF THE SURGEON-GENERAL
OF THE NAVY FOR 1880.]

WASHINGTON:
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EXTRACT FROM THE REPORT OF SURGEON-GENERAL P. S. WALES, U. S. NAVY, FOR 1880.

Two years ago a small laboratory was established in Washington for the investigation of the causative relation of the atmosphere and its impurities to the origination and extension of disease. This work has steadily progressed, with the aid of a small appropriation made at the last session of Congress, and it is now the intention of the bureau to increase the usefulness of this institution by widening its scope of investigation to all matters connected with the prevention of disease and the maintenance of health. This important work involves the collection from various sources of instruments, appliances, inventions, and designs relating to, and illustrating the progress of sanitary science in its widest application to the exigencies of civil and military life. It is intended to invite the co-operation of all classes interested in sanitary reform, so as to secure contributions to the collection, which, in a few years, will thus afford the most ample material for the exemplification of the courses of lectures to be delivered upon sanitary science.

It will be seen from the following report of Surgeon J. H. Kidder that the labors of the laboratory have been pushed with commendable zeal and earnestness, and, it is hoped, not without promise to the cause of future scientific investigation. He says:

> Agreeably to your instructions, observations of the chemical and microscopical constituents of the out-of-door air in the neighborhood of the laboratory have been carried on throughout the year. These observations will be the subject of a special report now in course of preparation.
>
> The other work of the laboratory has consisted in chemical examinations of substances presented by the department; microscopical examination of pathological specimens; numerous photo-micrographs; examination and consolidation of the meteorological reports from ships and stations; special investigations undertaken by your order.
>
> The *materiel* of the laboratory has been increased during the year by a small Carré ice-machine, a Browning's "Model" spectroscope, a Browning's small electric lamp with battery of 20-quart Bunsen cells, a large "College" lantern, for the exhibition of photographs upon a screen, and the usual replenishments of expended material.
>
> The total number of chemical examinations for the year is 267, which may be classified as follows:

Atmospheric carbon dioxide, quantitative	99
Comparisons of different methods for estimating atmospheric carbon dioxide	26
Air (by atomization), partly quantitative	20
Air (by condensation), partly quantitative	3
Rain, partly quantitative	3
Snow, partly quantitative	2
Examinations of Nessler process (see Report on Air), quantitative	6
Examinations of photographic chemicals, qualitative	4
Examinations of laboratory supplies, qualitative	23
Urine, qualitative	19
Urine, quantitative	23
Potable water, quantitative	5

Urinary calculus, qualitative	1
Stomach for potassium cyanide, qualitative	1
Intestinal concretion, qualitative	1
Fluid extract of ergot, qualitative	1
Green soap, qualitative	2
Pills, for morphia, qualitative	1
Pills, for lead and strychnia, qualitative	1
Whisky and brandy, qualitative	3
Lime juice, qualitative	5
Fly paper, qualitative	1
American Wood Preserving Company's process, quantitative	2
American Wood Preserving Company's process, quantitative (by Dr. Flint)	6
Chrome ore, qualitative	2
Copper alloy (ship nails), quantitative	4
Scheme for examination of copper alloys from a single specimen, quantitative	1
Oak and pine sheathing, for agent protecting the same against teredo, quantitative	2

Of the 267 analyses, 172 were quantitative, 67 qualitative, and 28 partly quantitative.

One hundred and fifty microscopic specimens have been mounted and preserved, a list of which is herewith inclosed.

Besides those above noted, many specimens were examined which were not considered as worth preservation. A large proportion of those microscopic specimens mounted since September 15 have been prepared by Dr. Griffith. A list is also inclosed of 82 photo-micrographs, which are now available for distribution.

Meteorological returns from 21 ships have been examined and reduced to graphic form by Surgeon James M. Flint and Passed Assistant Surgeons H. G. Beyer and S. H. Griffith.

Special examinations have been made of the working and economic value on shipboard of the Carré ice-machine, of blood from several cases of beri-beri admitted into the New York naval hospital, and of the instruments received.

About 60 of the boxes containing sets of tubes and disks, described in my last annual report (see report of the Surgeon-General of the Navy, 1879, p. 47), have been prepared and sent out. Only six have as yet been returned, of which four appear to have been prepared in accordance with the instructions. Examination of these four has not yet been completed, and will be made the subject of a special report. The offer made in your report for 1879 (p. 51), to send sets of the photographs therein referred to to those who should make application for them, has been extensively taken advantage of, and sets of the photographs distributed accordingly.

Surgeon Kidder represents that the operations of the laboratory would be materially facilitated by an increase of available space. There is especial need of a separate weighing room, the valuable balance now in use being in constant danger from the corrosive vapors often present in the laboratory, and of another room for instruments of special application, such as the spectroscope, lantern, and electrical apparatus.

The following is the special report of Surgeon Kidder, above referred to:

Air is supposed to modify the health of men and animals—

1st. By variations in the proportionate quantity of its *essential constituents*, viz, oxygen and nitrogen.

2d. By variations in the proportionate quantity of certain constituents which are *constant*, but not essential—aqueous vapor and carbon dioxide, for example.

3d. By containing extraneous substances, such as ammonia and other products of decomposition, nitrous and nitric acids, solids (mostly inorganic) dissolved in the aqueous vapor, and insoluble bodies drifted with the air as dust, including a multitude of organisms.

4th. By changes in its physical conditions of temperature and pressure.

Of the essential constituents of the air, *nitrogen* is inert, and need not be considered in this connection. *Oxygen*, the component of vital importance, does not, so far as we know, modify health perceptibly within the limits of its observed variations. Mr. R. Angus Smith, after an elaborate comparison of several thousand analyses* concludes that a fair statement of the composition of pure outside air would be—

	Per cent.
Oxygen	20.96
Nitrogen	79.00
Carbon dioxide	.04

The observed variations from these figures, whether the speciments examined were collected upon the mountains of Ecuador or in the suburbs of Manchester, have been found for the most part in the second place of decimals. And although the variations in the percentage of out-door oxygen are by no means always wholly accounted for by a corresponding excess of carbon dioxide, and it is quite conceivable that those gases which, under certain circumstances, take the place of the missing oxygen may be of so a hurtful a nature as to give an inferential significance to even very trifling diminutions in its quantity, chemical science is not yet competent to discriminate the hurtful from the harmless admixtures. In his well-known "lead-chamber" experiments, Mr. Angus Smith experienced no disagreeable sensation until the quantity of oxogen had fallen to 19.73 per cent. and that of carbon dioxide had risen to 1.13 per cent. It does not appear to me, moreover, that the resources of either the experimental laboratory or the present observer would be likely to add any facts of importance to the analysis cited by Mr. Smith, already referred to; and therefore no attempt has been made to estimate the percentage of oxygen in the air of Washington, which may be fairly assumed to be no exception in this respect to the rule which prevails in other parts of the world.

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* Air and Rain: London, 1872, pp. 6–42.

Atmospheric moisture affects the health of man in several different ways; when in excess it diminishes the drying power of the air; perspiration evaporates slowly or not at all, and the progress of this important secretion is proportionately checked. Moist heat is, therefore, felt to be particularly oppressive, not only because the escape of the animal heat of the body is impeded through diminished evaporation at the surface, but also because of the retention of important excrementitious matters which would otherwise find an outlet by way of the perspiration. Among such excrementitious matters have already been recognized urea, carbonic acid, formic, acetic, and butyric acids, neutral fats and cholesterine, most of which are poisonous to the circulation when long retained. That excessive moisture is not more immediately injurious than it is found to be is due to the excretory power of other organs, the liver, kidneys, lungs, and large intestines, which are overtaxed in proportion to the failure of the skin to properly perform its function. Moisture is also an essential factor in the disease-breeding processes of putrefaction, in the development of moulds and other deleterious low organisms, and in the development and spread of malaria, plague, small-pox, yellow fever, and the whole range of fluxes and rheumatic and neuralgic disorders. *"Dry air," on the contrary, "stimulates the skin, because it removes moisture, and the skin must set to work to renew it. Dry air, therefore, would in this respect be in its first effect cheering, and in its last irritating."

Notwithstanding these considerations, however, and the fact that no sanitary precaution is more generally recognized and observed than the avoidance of "dampness," it still remains true that "the condition of the air as regards humidity * * * has not hitherto been much considered."† It is, in fact, an exceedingly difficult matter to discriminate justly between the degree of importance of out-door humidity and that of other factors in producing disease; partly because so large a portion of the life of the people of this country is spent indoors, in apartments the climate of which differs widely from that outside, and partly because of the difficulty in separating humidity from other constituents and qualities of the air which must always accompany it. Of its influence under the more circumscribed conditions of life on ship-board a striking evidence is furnished by the graphic representations consolidated from the meteorological returns of the different ships of the Navy, by Surgeon James M. Flint, United States Navy.‡

Much has been said of late years respecting the advantages and disadvantages of a moist climate in the treatment of pulmonary disorders, not resulting as yet in a perfect agreement of opinion among medical practitioners. Mr. Meymott Tidy remarks that:§ "It has been noted that in certain places, remarkable as health resorts, the degree of saturation is singularly uniform.

Dr. Parkes‖ adopts as a provisional standard of the most wholesome degree of saturation 73 per cent., in another place between 70 and 80 per cent. Mr. Tidy suggests "beween 66 and 70 per cent.," and it may be said in general terms that a degree of saturation below 65 or above 80 per cent. is found to be uncomfortable, and is likely to be injurious to health.

Daily hygrometric observations have been taken during the course of the present investigation at 10 a. m. and 2 p. m., and are set forth at length in the tables at the end of his report. In the following abstract the highest, lowest, and average degree of humidity for each of the six months from January to July are shown, together with the average temperature at the times of observation. The average humidities for the whole time are stated in a separate column, abstracted from the Signal Service reports:

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* Angus Smith, *op cit.*, p. 137.

† Parkes' Hygiene, London, 5th ed., p. 146.

‡ See Rep. of the Surgeon-General of the Navy, pp. 46, 57, 164, 188, 238, 276, and 306; also Air and Moisture on Shipboard, by Med. Dir. Thos. J. Turner; Hygiene and Med. Reps., 1879, p. 667, and Naval Hygiene, Med. Dir. A. L. Gihon, Washington, 1873, pp. 35–38.

§ Handbook of Modern Chemistry, London, 1878, p. 100.

‖ Hygiene, pp. 147 and 437.

TABLE I.

Months.	Relative humidity. Saturation = 100.			Mean temperature, 10 a. m. and 2 p. m.	Mean relative humidity from hourly observations.
	Maximum.	Minimum.	Mean.		
1881.					
January	70	34	52.1	53	77.6
February	82	34	55	57.2	73.4
March	78	42	57.4	50.9	67.3
April	92	37	63.6	61.5	66.0
May	90	54	74.1	71.5	69.3
June	92	51	76.1	75.2	72.8

It appears from the above table that the monthly means of relative humidity observations made in the day-time show a progressive increase corresponding to the monthly increment in mean temperature; while observations made hourly by the signal service during the same period show no differences corresponding to seasonal changes of temperature; the night observations probably compensating by increased figures for the lower humidities during the warmer parts of the day in cold weather, and *vice versa* as the average temperature increases.

During the five months from February to June, inclusive, almost daily determinations of *carbon dioxide* have been made.* The method known as Pettenkoffer's was followed and the air examined was from the immediate neighborhood of the Naval Dispensary at the corner of Eighteenth and K streets, n. w. The quantity of carbon dioxide thus determined has been for the most part very large; so large as to give ground for alarm if there really be any constant relation between the quantity of this gas and of organic matters in the air. The table of estimations which follows shows a variation ranging from 0.241 to 1.961 parts (by volume) in 1,000, a variation so unusual as to excite suspicion as to the accuracy of the observations. For this reason I have taken especial pains to verify the titrations of the reagents employed, and have made a careful examination of such causes of error as suggested themselves, with a long series of comparative simultaneous observations by lime-water, baryta water, and determinations by weight, passing the dried air through solution of caustic potassa and dry potassium hydrate. In these observations I have had the benefit of the assistance of Passed Assistant Surgeons William H. Dixon, H. G. Beyer, and S. H. Griffith, whose results have been similar to my own. I am, however, unwilling to believe that the actual contents of Washinton out-door air in carbon dioxide often reaches so high a figure as one part in one thousand, preferring to suppose that the occasional excess observed was due to some accidental contamination local to the place of observation.

The mean of ninety-six observations is 0.766 part, by volume, per thousand; and, although this quantity is considerably in excess of that accepted as normal in good out-door air, I am constrained to believe that it is very near the true proportion usually present in the locality examined.

It has been suggested that the excess of carbonic acid, so generally observed near the experimental laboratory, may be due to the neighborhood of several lime-kilns, about three-quarters of a mile to the westward. For want of a better, I am disposed to adopt this explanation, although the table shows no constant connection between the quantity of this gas and the direction of the wind. Whether this be so or not, it is probable that the quantity of carbon dioxide in the air bears no relation to the quantity of dangerous organic matter, and that the importance of determinations of the quantity of this gas as an index to organic contamination has, doubtless, so far at least as outside air is concerned, been vastly overrated. Although not a few hygienic chemists, when called upon to make "air analyses," have contented themselves with determining the parts per thousand of carbon dioxide, and its importance as an indicator of organic contamination and consequent unhealthfulness of air has been very generally admitted without question; more extended experience has tended rather to discredit than to establish its value. The "lead chamber" experiments of Mr. Angus Smith, already referred to (page 285), and the large quantities of carbon dioxide given off from coal, as shown by special observations made by order of the department in the United States ships Kearsarge, Trenton, Tennessee, Alliance, and Wyoming, considered in connection with the total want of relation between the quantity of this gas and the number of sick observed in all ships of the Navy of which the meteorological records had been examined for the year 1879, have led the Surgeon-General of the Navy to indorse the conclusion of Surgeon J. M. Flint, that "the amount of carbon dioxide, as recorded, seems to be no just measure of the condition of ventilation or of the respirability of the air."*

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* Passed Assistant Surgeon C. U. Gravatt has called the attention of the bureau to a simplification of the process of calculating the amount of atmospheric carbonic acid now in use by the medical officers of the Navy, which, he says, has recently been suggested to him by Passed Assistant Surgeon Robert Swan, and by which considerable time may be saved and much of the personal error, so liable to creep into all mathematical calculations, avoided.

"It consists in employing a factor by which the difference of alkalinity of the lime-water before and after exposure may be multiplied and at once show the amount of carbonic acid without first multiplying by the decimal .795 and then dividing by the capacity of the jar. A correction for temperature has, of course, to be applied as before.

"The constant for each jar is determined by once going through the ordinary method and dividing the amount of carbonic acid obtained (before correcting for temperature, &c.) by the difference of alkalinity.

"The number so found will afterwards hold good for any degree of difference. The accuracy of this plan has been repeatedly verified and is now in use on board this ship. It is communicated in order that whatever advantage it possesses may be utilized.

"It might be well to have the factor for every jar determined before being issued and a table constructed after the manner of those for obtaining relative humidity, to at once show the amount of carbonic acid for each tenth cubic centimeter, going as high as may be deemed necessary.

"All that would then remain to be done would be to test alkalinity, read off the corresponding quantity of carbonic acid, and apply the usual corrections for temperature and barometric pressure. Simplifying the ordinary method may prove advantageous by encouraging more frequent observations than are oftentimes made."

In the detailed statement which follows (Table II), there does not appear to be any constant relation between the quantity of carbon dioxide in the air and either temperature or relative humidity, although the proportion was often diminished during or after a rain. There was often found to be a larger proportion of carbon dioxide in the air of the laboratory yard than in that of the street near by, due, as I suppose, to the presence of grass and shrubs, with probably a certain amount of decomposing organic refuse in the former. The air in the street, it is to be noted, never contained so much as 1 part in 1,000 of carbonic dioxide, although often exceeding the normal average.

TABLE II.—*Estimations of carbon dioxide in laboratory yard.*

Date.	Hour.	Temperature.	Relative humidity.	Wind.	Observer.	CO_2 parts per 1,000.	Remarks.
1881.		°					
Feb. 19	12 m	55	68		J. H. K.	0. 999	Damp.
21		60	55		do	0. 600	
22		49	62	W.	do	0. 937	
23		65	55	NW.	do	0. 970	
24	1 p. m	61	40		do	1. 040	Snow at night.
25	3 p. m	60	50		do	0. 807	
28	2 p. m	60	70		do	0. 600	Rain yesterday.
Mar. 2	2 p. m	58	44	NW.	Dr. Dixon.	0. 870	
3	2 p. m	52	28	NW.	do	0. 810	
7	3 p. m	55	54		do	0. 700	
8	3 p. m	55	43	S. SE.	do	0. 500	
9	5 p. m	46	70	NW.	do	0. 590	Rain.
10	3.45 p. m	63	48	W.	do	0. 435	
12	3 p. m	43	70	S. SE.	do	1. 328	Do.
14	4.30 p. m	61	34	S.	do	0. 910	
16	5.30 p. m	61	58	W. by S.	do	0. 790	
17	3 p. m	51	74	E.	do	0. 519	
18	3 p. m	52	74	E.	do	0. 780	
19	3 p. m	59	42	W.	do	0. 875	
24	3 p. m	54	30	W.	do	1. 034	
25	3 p. m	61	40	W.	do	0. 529	Snow followed at night.
26	3 p. m	33	44	W.	do	0. 563	Snowing.
28	3.40 p. m	61	30	NW.	do	0. 529	
29	4 p. m	57	50	E.	do	0. 567	
30	4 p. m	40	50	W.	do	1. 097	
31	5.45 p. m	40	58	W.	do	1. 361	
Apr. 1	4.45 p. m	44	64	NW.	do	0. 899	Taken in street.
4	4.50 p. m	51	54	NW.	do	0. 426	Do.
5	4.15 p. m	42	(?)10	NW.	do	0. 510	Do.
6	3.30 p. m	47	24	NW.	do	0. 597	Do.
7	4.15 p. m	52	62	NW.	do	1. 220	Laboratory yard.
8	3.45 p. m	42	85	NE.	do	0. 469	Rain.
10	10.15 a. m	64	69	NW.	do	0. 532	Taken in street.
11	3 p. m	63	53	NW.	do	0. 796	Do.
12	5.15 p. m	60	84	NW.	do	0. 486	Do.
13	5.15 p. m	52	82	N.	do	0. 480	Do.
14	4 p. m	52	45	NE.	do	0. 780	Do.

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*Report of the Surgeon-General of the Navy, 1879, page 46; also, graphic consolidations of meteorological reports of the several ships during the same year, pages 57, 164, 188, 238, 276, and 306.

Report on the subject of organic matter in the air, by Prof. Ira Remsen, National Board of Health Bulletin, September 11, 1880, page 517.

This fact is also fully borne out by the investigation of Passed Assistant Surgeon S. H. Griffith, who

TABLE II.—*Estimations of carbon dioxide in laboratory yard*—Continued.

Date.	Hour.	Temperature.	Relative humidity.	Wind.	Observer.	CO^2 parts per 1,000.	Remarks.
1881.		°					
Apr. 15	5 p. m.	57	45	NW.	Dr. Dixon	0.982	Taken in street.
17		60	66	W.	....do	0.950	Do.
18	2.45 p. m	66	57	E.	....do	0.241	Do.
18	2.45 p. m	66	57	E.	....do	0.878	In yard.
19	4.45 p. m	60	38	SE.	....do	1.003	
20	6 p. m.	52	62	E.	....do	0.645	
21	4 p. m.	64	50	S.	....do	0.426	
22	4.15 p. m	63	70	S.	....do	0.627	
24	8 p. m.	65	80	S.	....do	1.140	Examined 43 hours after collection.
27	2 p. m	72	60	W.	....do	0.855	
28	2 p. m.	72	60	W.	....do	0.486	
29	5 p. m.	72	66	W.	....do	0.583	
May 1	5.30 p. m	63	74	E.	....do	0.669	
2	4 p. m.	70	73	N.	....do	1.170	Cloudy
3	4 p. m.	62	80	E.	....do	0.615	Do.
4	4 p. m.	60	80	E.	....do	0.528	
5	4 p. m.	63	60	E.	....do	0.444	
6	4.30 p. m	66	84	W.	....do	0.939	
7	3.15 p. m	68	68	SE.	....do	0.653	
9	2 p. m.	74	79	S.	....do	0.629	

says that, "according to the reports from the Richmond, on board of which vessel are improved ventilating appliances, and where observations were carefully made under varying conditions, the average of thirty observations, taken when the ventilators were working, gives 1.297 parts of carbonic acid per thousand; the average of sixteen observations, taken when the ventilators were not working, gives 1.102 parts per thousand—a higher result when the ventilators were working.

That humidity has much to do with the amount of sickness seems to be shown. There are exceptions, where high relative humidity of the berth deck goes with a relatively small percentage of sick, as the Tennessee and Powhatan, and *vice versa* in the reports of the Ticonderoga and Minnesota; but there is a general correspondence between high humidity and large percentage of sick when the number sent to hospital is taken into account. In many of the exceptional cases there are evident reasons for the departure from what seems to be the rule, *e. g.*, the Ticonderoga, on a special cruise, with a crew enfeebled by exposure, along the African coast, where many of the men were attacked with fever; the Minnesota, with a crew composed mostly of boys, unaccustomed to the exposures, &c., incident to the service.

The following table shows the percentage of sick, number sent to hospital and invalided, and the relative humidity for twenty-one ships, arranged in order of humidities:

Ships.	Percentage sick.	To hospital and invalided.	Relative humidity.		Remarks.
			Berth deck.	Spar deck.	
Saint Louis	1.41	12	59.2	55.3	Receiving-ship, League Island.
Wabash *	.88	14	61.4	61.9	Receiving-ship, Boston.
Franklin	.52	20	62.8	66.2	Receiving-ship, Norfolk.
Minnesota	2.77	84	67.1	70.1	Training-ship.
Independence*	1.26	7	68.7	64.8	Receiving-ship, Mare Island.
Ticonderoga	5.42	24	69.1	70.3	Special service.
New Hampshire	1.17	2	70.9	74.6	Port Royal, training-ship.
Kearsarge	1.64	7	72.1	69.8	North Atlantic station.
Nipsic	2.89	1	73.5	70.9	European station.
Constitution	2.91	78	73.9	75.2	North Atlantic station.
Pensacola	2.98	54	73.9	77.5	Pacific station.
Saratoga	1.02	22	74.4	75.7	Training-ship.
Alaska	1.60	13	75.5	82.6	Pacific station.
Lackawanna	1.52	15	75.6	81.1	Do.
Marion	2.18	7	75.7	82.8	South Atlantic station.
Shenandoah	2.93	15	75.8	78.2	Do.
Richmond	1.43	15	77.2	82.8	Asiatic station.
Tennessee	1.24	15	81.0	68.1	North Atlantic station.
Wachusett	4.68	8	84.6	85.4	South Atlantic and Pacific station.
Powhatan	1.93	22	85.7	71.7	North Atlantic station.
Alliance	3.78	25	88.0	81.6	Do.

* Roofed over.

The largest percentage of sick was on the Ticonderoga, noted above; next is the Wachusett, with relative humidity of 84.6 and 4.68 per cent. of sick. The Alliance, with the greatest humidity, 88, has 3.78 per cent. of sick (for 8 months), besides sending 25 to hospital."

TABLE II.—*Estimations of carbon dioxide in laboratory yard*—Continued.

Date.	Hour.	Temperature.	Relative humidity.	Wind.	Observer.	CO^2 parts per 1,000.	Remarks.
1881.							
11	4.15 p. m	87	66	W.	do	0.644	
12	3.30 p. m	89	66	W.	do	0.646	
13	2 p. m	89	63	NW.	do	0.691	
15	8.30 a. m	78	74	W.	do	0.509	
16	4 p. m	79	64	SE.	do	1.036	
17	4.30 p. m	69	74	E.	do	0.494	
18	5.15 p. m	67	77	N.	do	0.578	
19	11.30 p. m	64	83	W.	Dr. Beyer	0.889	
20	5 p. m	77	69	W.	do	1.830	
31	4 p. m	86	88	SE.	do	1.393	
June 1	4 p. m	82	76	NW.	do	1.823	
2	4 p. m	71	74	E.	do	0.997	
3	6.45 p. m	75	69	E.	do	0.914	
4	11 a. m	66	80	E.	do	0.673	
5	4 p. m	69	77	E.	do	0.763	
6	4.45 p. m	72	82	E.	do	0.420	
7	4 p. m	70	83	E.	do	0.449	
8	5 p. m	82	85	W.	do	0.554	Cloudy.
9	5 p. m	70	85	E.	do	1.057	Do.
10	4.30 p. m	62	80	W.	do	0.400	Clear.
11	5 p. m	68	80	W.	do	0.628	Do.
12	5 p. m	74	74	E.	do	0.679	Do.
13	5 p. m	75	74	E.	do	0.320	Do.
14	5 p. m	83	60	W.	do	0.923	Do.
15	4 p. m	81	60	W.	do	0.461	Do.
16	4 p. m	79	63	W.	do	0.572	Do.
17	5.30 p. m	82	80	W.	do	0.507	Do.
18	4 p. m	80	65	W.	do	0.547	Do.
19	10 p. m	80	80	W.	do	0.571	Do.
20	5 p. m	85	77	W.	do	0.692	Do.
21	7 p. m	80	68	W.	do	1.249	Do.
22	4 p. m	74	70	W.	do	0.883	Do.
23	11 p. m	74	70	NE.	do	0.982	Do.
24	5 p. m	73	74	W.	do	0.881	Do.
25	4 p. m	76	78	NE.	do	0.686	Cloudy.
26	5 p. m	77	83	E.	do	0.686	Do.
27	4 p. m	79	82	W.	do	0.374	Rain.
28	5 p. m	86	67	S.	do	0.461	Clear.
29	4.30 p. m	85	82	W.	do	0.846	Rain.
30	5 p. m	85	70	W.	do	1.961	Cloudy.

AMMONIA.

The fact, first noted by Gay-Lussac, that all of the nitrogen of organic matters, when they are heated with caustic hydrates, appears as ammonia, has been the basis of most of the more recent estimations of organic matter in the air, the Nessler process being usually preferred for this purpose to that of Varentrapp and Will, on account of its greater delicacy. Granting the substantial trustworthiness of the Nessler process, at least for comparison of the relative contents in nitrogenous organic matters of different samples of air washings, a serious practical difficulty presents itself when attempts are made to get *all* of the nitrogenous matter in a measured sample of air into the washings. Aspiration of bubbles of air, through water, fails entirely, owing to the relatively large contents and small surface of the bubbles, which are but a short time in contact with the water through which aspiration is done. Mr. Angus Smith's method of repeated washings of successive bottles full of air with the same water requires, certainly, almost unlimited patience, "and it is very questionable," as Prof. Remsen remarks, "whether complete absorption can be effected in this way."* Minute division of the air, and its more perfect contact with the washing water, has been effected at the Montsouris Observatory by aspiration through several vessels ("absorbers") containing water, wherein the air is finely divided at the bottom of each by passage through a fine "rose" of glass or platinum; and Mr. Dixon has improved upon this procedure, at Glasgow, by introducing a number of glass beads into each "absorber," whereby the air is still further comminuted and detained for a longer time in contact with the washing water.†

The very efficient "absorber," used by Prof. Ira Remsen, in his experiments for the

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* Bulletin of the National Board of Health, September 11, 1880.

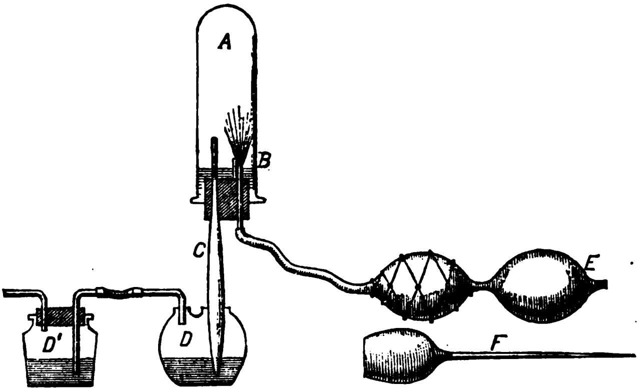
† Water, Air, and Food. By Cornelius B. Fox; Philadelphia, 1878, pp. 279, 284.

National Board of Health,* consisted essentially of moderately fine pumice stone heated to redness, moistened with water, and put into tubes through which the air to be examined was aspirated by appropriate apparatus.

In all of the procedures above mentioned, as well as in that followed in my experiments, the variations have been in the modes of separating organic matter from the air, its determination having been in each case by the Nessler process.

I have used, in my experiments, an apparatus devised by Dr. Fox, which brings "continually fresh quantities of air into intimate contact with a small quantity of very pure water, which is reduced to a minute state of subdivision by pulverization."†

FIG. 1 (after Fox).



A, glass cylinder, closed by rubber stopper, through which pass B, a Richardson's atomizer cut short, and C, a glass tube ground as a stopper into the bottle D. Air is forced in by the hand-pump E, atomizes the water in A, and passes out by the tube C, carrying a small portion of the atomized water with it, which is stopped in the bottles D and D'. In D the tubes are ground to fit as stoppers; D' is closed by a perforated rubber stopper; F, pipette and rubber tube for washing.

By referring to the accompanying figure, it will be seen that the air and water are comminuted by this device probably as finely as possible, and brought into intimate contact with one another. The air can, moreover, be measured with reasonable accuracy, so that there is good reason to expect to find in the water all of the contained solids which are small enough to pass through the jet of the atomizer, and all of the gases and salts soluble in water. An important advantage in this apparatus is the very small surface exposed to the washing process, since Angus Smith has found‡ that ammonia attaches itself and adheres to surfaces exposed to the air, in relative quantity much greater than that found in the air at the same time. A glass surface of 30 square inches, for example, exposed for half an hour and washed with distilled water, furnished a quantity of ammonia varying from 0.002 milligrams in exceptionally pure air to 1.1 milligram over a "midden" (p. 24). It is to be noted, also, that these washings were always, in Mr. Smith's experiments, Nesslerized directly, without distillation or addition of potassium hydrate and permanganate. The quantities obtained stand therefore only for the *free* ammonia present. The presence of the ammonia is due, as the experimenter thinks, to the decomposition of the organic matters in the air dust which has collected upon the surfaces examined, an opinion to which my own observations upon certain forms of "air crystals" lend some support.§ I had observed the same fact at the time of my report to the Surgeon-General last year, when I remarked that I could "see no reason why ammonia, or an *amine* responding to the Nessler reagent, should always have appeared in the moisture condensed directly from the air (upon cold surfaces), and not at all from water through which air had been passed at the same time and place."‖

In addition to the apparatus represented in the figure, there were used in the estimations a small glass Liebig's still, a small retort, the usual Nessler reagent, and a set of very small Nessler tubes, graduated, and holding but 10 c. c. each.

The procedure has been as follows: The glass dome and all the parts of the apparatus were washed out with freshly-distilled water; 70 c. c. of the same were measured, and about one-third introduced into the dome-tube, and each of the washing-bottles, which were then connected with each other and with the atomizer. Ten closures of the hand-ball were found to displace an average of 330 c. c. of water in an upright graduated tube, and 3,100 closures of the hand-ball were made for each estimation, so as to get the full measure of 100 liters of air, with an allowance of 2.3 liters for the probably occasional accident of imperfect emptying of the hand-ball, and for defective valves. At the close of the experiment the apparatus was emptied into a clean glass-stopped bottle, and washed with 30 c. c. of freshly-distilled water by aid of the ball pipette. The washings were added to the original 70 c. c., and the resulting 100 c. c. Nesslerized, as in water analysis. But 10 c. c. of distillate were examined for free ammonia, the usual correction of one-third added, and distillation proceeded with until 40 c. c. had passed over. To the residue in the retort, 10 c. c. solution of potassium hydrate and permanganate were then added, and three successive portions of 10 c. c. each of distillate Nesslerized for "albuminoid" ammonia. In Nesslerizing, but half a cubic centimeter of the Nessler reagent was added to each sample. The same quantity was put into an empty glass, which was filled to 10 c. c. with distilled water from the same lot that had supplied the washing water, and the weak solution of ammonium chloride (1 c. c. $=\!\bigcirc\!=$ 0.01 milligram ammonia) added lastly, by tenths of a cubic centimeter, until the tint of the assay had been matched as nearly as possible. By this procedure any ammonia which might be present in the distilled water was detected at the start and duly allowed for. In point of fact, it was very rare that the distilled water used, in the preparation of which much care was taken, showed a tint sufficiently pronounced to be measured. Blank experiments were frequently made, with results never exceeding 0.005 milligrams of ammonia.

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* Op. cit.

† Water, Air, and Food, page 286.

‡ Sixteenth annual report, by the inspector of alkali works, of his proceedings during the year 1879. London, Eyre & Spottiswoode, 1880, p. 19.

§ Report of the Surgeon-General of the Navy, 1879, p. 49.

‖ *Id.* p. 51.

In estimating the quantity of atmospheric organic matter, either by the method just described, by condensation of atmospheric moisture upon cold surfaces, or by Nesslerizing the first of a snow or rain fall, it often, but not always, happened that the color struck by the Nessler reagent differed so decidedly from that artificially produced in solutions of ammonium chloride, used for comparison, as to make it difficult to determine the point of nearest approximation in tint. When free ammonia was present in sufficient quantity to give a reaction without distillation, such variation from the standard ammonia tint was observed but once (experiment 5). In the estimation of free ammonia by distillation, the color produced was often a vivid yellow, less often yellowish-green; while a green tint tended to predominate in the estimations of "albuminoid" ammonia, *i. e.*, after the addition of potassium hydrate and permanganate to the residue in the retort.

In the following tabulated statement of nineteen estimations of ammonia in samples of air collected "by atomization," these variations in color have been noted as "Nessler reaction," together with such other conditions of the experiments as have appeared to be of consequence in this connection.

TABLE III.—*Estimations of ammonia, per cubic meter of air, by "aspiration."*

No.	Date.	Locality.	Free ammonia, before distilling.	Free ammonia, after distilling.	Albuminoid ammonia.	Temperature, Fahr.	Relative humidity, saturation = 100.	Carbon dioxide, parts per 1,000.	Remarks.
	1881.		*Milligrams.*	*Milligrams.*	*Milligrams.*	*Degrees.*			
1	Jan. 20	Mineral room, Smithsonian Institution.	....	0.156	0.216	75	....	....	Amorphous white residue; starch, vegetable fiber, silicate of alumina, long bacilli in rapid motion; dendritic crystals on evaporation. Nessler reactions normal.
2	Jan. 20	West basement, Smithsonian Institution.	....	0.130	0.180	65	....	....	Room used for storing alcoholic specimens of fish, strong odor of propylamin; specimens contain long bacilli as above; occasional epithelial scales. Nessler reactions normal.
3	Jan. 26	Open air, yard	....	0.141	0.220	57	54	....	Deposit mostly silicate of alumina; no bacteria or bacilli. Nessler reaction yellow for free ammonia.
4	Jan. 27	Clerk's office, Bureau Medicine and Surgery, Navy Department.	....	Less than 0.005	Less than 0.005	80	Very low.	....	Quantity of ammonia too small to be estimated; very scanty deposit; long, active bacilli.
5	Feb. 4	Laboratory yard	Trace.	Lost.	0.065	Below 32	....	....	No rain or snow for 72 hours; very little residue, mostly silicate of alumina. Nessler reaction green, before distilling, also in No. 1 albuminoid; Nos. 2 and 3 albuminoid normal.
6	Feb. 5	......do	....	0.160	0.070	46	34	....	Scanty residue, mostly silicate of alumina, with old vegetable fiber. Free ammonia Nesslerizes of normal color; albuminoid shows distinct green.
7	Feb. 15	......do	....	0.130	0.120	62	43	....	Residue scanty; of no especial interest. Nessler color not noted.
8	Feb. 19	......do	....	0.175	Lost.	48	72	0.990	After rain. Nessler color a vivid *yellow*; no shade of brown or green.
9	Feb. 20	Fort Corcoran, Va. (west of Washington).	....	0.087	0.090	54	....	....	Nessler color, *greenish yellow* for free ammonia; normal for albuminoid.
10	Apr. 13	K street, near laboratory....	....	0.067	0.125	52	82	0.480	Nessler color, *greenish yellow* for both free and albuminoid estimations.
11	Apr. 15	Laboratory yard	....	0.200	0.100	52	45	0.982	Wind northeast; [illegible] north, [illegible]ler color, bright *yellow*, for free; *greenish yellow*, for al[illegible] ammonia.
12	Apr. 19	K street, near laboratory....	....	0.130	0.110	59	46	1.008	Wind no[illegible] [illegible]r color, strong *yellow*, for free; norm[illegible] [illegible]nia.
13	Apr. 26	Laboratory yard	....	0.098	0.100	79	64	....	Wind [illegible] [illegible]ia, vivid [illegible] [illegible]uminoid, [illegible]or [illegible]
14	Apr. 28	K street, near laboratory....	....	0.040	0.024	78	62	[illegible]	[illegible] west [illegible] of a [illegible]
15	May 18	Laboratory yard............	....	0.240	Trace.	68	70	0. [illegible]	W[illegible] the [illegible]

16	May 26	Laboratory yard	....	0. 067	0. 200	73	78	....	Wind east; clear weather; deposit mostly vegetable *débris*. Nessler color not noted; nitrites and crystals.
17	June 15	......do	....	0. 093	0. 180	80	62	0. 4615	Wind west. Nessler color, *greenish-yellow*, for free ammonia; normal, for albuminoid.
18	July 30	......do	....	0. 066	0. 030	83	56	....	Wind west. Nessler color not noted.
19	Aug. 30	East window, third story, southeast wind.	....	0. 093	0. 050	85	72	....	Wind southeast; towards the end of a very long season of dry weather. Nessler colors normal in both reactions.

From an analysis of the foregoing table it appears that in nineteen observations made at intervals during six months the "Nessler color" varied as follows:

In 8 both free and albuminoid were normal or not noted;
In 4 free ammonia was *yellow*, albuminoid normal or not noted;
In 2 free ammonia was *greenish-yellow*, albuminoid normal or not noted;
In 2 free ammonia was *yellow*, albuminoid *greenish;*
In 1 free ammonia was *greenish-yellow*, albuminoid *greenish-yellow;*
In 1 free ammonia was *yellow*, albuminoid *greenish-yellow;*
In 1 free ammonia was *green* before distillation, not noted after distillation, and the first albuminoid distillate *greenish*, the second and third being normal.

As regards *locality* an analysis of the table shows the colors to have been normal or not noted in two specimens from the Smithsonian Institution, notwithstanding the odor of propylamin in Exp. 2; in one from the clerk's office of the Bureau of Medicine and Surgery; in the laboratory-yard four times; on K street near the laboratory once; and in a window opening to windward, 30 feet above the street (after a prolonged drought) once. Albuminoid ammonia gave the normal color, while free ammonia struck either yellow or greenish-yellow four times in specimens from the laboratory-yard, in one specimen from K street, and in one from Fort Corcoran, outside of the city limits. Both free and albuminoid showed abnormal tints in the laboratory-yard twice, and in K street, near the laboratory, twice. Albuminoid reaction was green, free ammonia being normal in one specimen taken in the laboratory-yard.

In specimens of rain and snow, which were Nesslerized at various times, both free and albuminoid ammonia gave the normal tint in three instances, yellow before distillation in one, normal before distillation, and yellow afterward for free ammonia, albuminoid being normal, in one. And in specimens of moisture condensed upon cold surfaces, both free and albuminoid reactions were normal in one instance before and after distillation; free ammonia green both before and after distillation in one, albuminoid remaining normal; and in one case, in which the quantity collected was too small for distillation, the color was normal.

It appears then, from the foregoing analysis, that the cause of these variations in color is not always present out of doors, that it has not been observed in any of the few specimens taken in doors, and that it does not appear to depend upon any cause local to the places examined. The difference in quality of color is distinct and decided, the foreign material giving in all cases a tint, either yellow or greenish-yellow, of more pronounced quality and at the same time greater transparency than the normal; so that when the column of colored liquid is viewed vertically the tendency is to underestimate the quantity of ammonia present, while if viewed transversely or obliquely the tendency is to overestimate it. I have not observed similar variations in Nesslerizing potable waters, or in any artificial ammonia solutions, and it therefore does not appear to me possible that they can be due to impurities in the reagents used; nor have I as yet found any mention of the phenomenon in such authorities as have been accessible to me.

I have supposed that the cause of the variations would be found in the occasional presence of other *amines*, wherein one or more atoms of hydrogen are replaced by compound radicles containing carbon; and that such *amines* result from putrefactive changes of organic matter, either in the air itself or upon surfaces exposed to the air. This notion gets some support from Mr. Angus Smith's theory that the relatively larger quantity of ammonia found upon surfaces is due to decomposition of the organic part of the air dust on the surfaces themselves. The theory is an attractive one, but is not supported by the few experiments which it has been possible to make as yet in the direction of testing it. These experiments are far too imperfect to warrant any decided conclusion, and are detailed here only by way of suggestion, in the want of leisure to go farther with them at present.

1. Two drops of *fluid extract of ergot* (containing propylamine) in 100 c. c. of distilled water, when distilled, gave, upon Nesslerization, only the normal ammonia color reaction.

2. *Butyrates of sodium and calcium* in very dilute solution in distilled water (free from ammonia) gave, upon distillation, both before and after the addition of potassium hydrate and permanganate, the clear *greenish-yellow* which has often been observed in air examinations.

3. *Carbonate of ammonia* in distilled water (about 0.2 per cent.) when distilled gives dense ammonia color reaction, both before and after treatment with potassium hydrate and permanganate, showing on dilution no trace of the abnormal color.

4. *Acetic*, *butyric*, and *formic* acids, and a mixture of the three, all largely diluted, were Nesslerized without distillation. Acetic and formic acids were unaffected; butyric acid gave the normal ammonia brown-yellow.

5. The butyric acid solution of experiment 4 was distilled (after previous addition of Nessler reagent) and tested as for free ammonia; very faint normal ammonia reaction.

6. A small quantity of distilled water from the common wash-bottle was redistilled and the distillate Nesslerized; reaction for normal ammonia. After about one-half had gone over and, presumably, no free ammonia remained, added 4 drops of butyric

acid and continued the distillation. A faint reaction, *greenish-yellow* color. This experiment was made to ascertain whether the normal ammonia noted in experiment 4 existed as an impurity in the butyric acid—as butyrate of ammonia for example.

7. To the liquid remaining in the retort after experiment 6 added lime water; a brownish precipitate (impure calcium butyrate). Distilled one-half and Nesslerized; distinct indication of normal ammonia, introduced as I suppose with the lime water. Added potassic hydrate and permanganate to residue in the retort, resumed distillation, and Nesslerized; pale but distinct *greenish-yellow*.

So far as these rough experiments show anything they indicate that the abnormal tints observed in the Nesslerization of air specimens may be produced from butyrates of sodium and calcium after distillation, both before and after treatment with potassium hydrate and permanganate; that butyric acid alone gives the normal ammonia reaction before distillation, acetic and formic acids being unaffected, and that the ammonia observed probably does not exist as an impurity in the butyric acid. It farther appears from the ergot experiment (experiment 1) that the abnormal color is not due to propylamine. There is no reason to suppose that butylamine is formed in any part of the experiments described. The indication, so far as I have gone, is that products of the decomposition of organic matters other than ammonia are capable of responding to the Nessler reagents, with a distinct difference in color, and that such substances are not necessarily *amines*. Upon the accompanying sheet I have endeavored to match the colors observed, contrasting the normal ammonia tints with those of butyrate of sodium, examined as for albuminoid and free ammonia. The latter closely approximate the *yellow* and *greenish-yellow* tints observed in air analysis.

Reverting to Table III, it appears that the largest quantity of free ammonia observed in one cubic meter of air was 0.240 milligram in the laboratory yard, May 18, the least 0.040 milligram, in K street, near the laboratory. In Table IV these observations are compared with some results obtained in other localities and by various methods.

TABLE IV.—*Estimations of free ammonia in one cubic meter of external air.*

Observer.	Locality.	Maximum.	Minimum.	Mean.	No. of observations.	Mode of collection.
		Milligrams.	*Milligrams.*	*Milligrams.*		
* R. Angus Smith ..	London and vicinity....	0.203	0.028	0.061	18	Air washed by shaking in bottle with water.
† R. Angus Smith ..	Laboratory and vicinity	0.190	0.071	0.122	10	Do.
* R. Angus Smith ..	London Underground Railway.	0.109	0.034	0.072	2	Do.
* R. Angus Smith ..	Glasgow	0.101	0.036	0.078	4	Do.
‡ William Dixon (?)	Manchester	....	....	0.093	1	Do.
‡ William Dixon (?)	......do	....	...	0.070	1	Aspiration through water.
§ Ira Remsen.......	Baltimore...............	0.157	0.064	0.097	11	Aspiration through pumice stone.
J. H. Kidder	Washington	0.240	0.040	0.115	18	Atomization of water with air.

* Air and Rain, pp. 432–434.
† Many of these observations made indoors.
‡ Water, Air, and Food, p. 285.
§ Report on Organic Matter in the Air. National Board of Health Bull., September 11, 1881, p. 520.

Excluding Mr. Angus Smith's series of observations made partly indoors (the second series of the table), the quantity of ammonia found in a cubic meter of air increases in proportion to the effectiveness of the mode of collection. Simple aspiration gives the smallest quantity; shaking of successive portions of air with the same quantity of water follows next; aspiration through pumice-stone and atomization furnish the largest quantities observed. Separating my observations according to the localities of collection, the results will appear as in Table V.

TABLE V.—*Milligrams of free ammonia per cubic meter of air.*

Locality.	Maximum.	Minimum.	Mean.	Number of observations.
Laboratory yard	0.240	0.066	0.137	10
K street, near laboratory	0.130	0.040	0.079	3
Smithsonian Institution	0.156	0.130	0.143	2
Bureau Medicine and Surgery	....	....	0.005?	1
Window of laboratory	....	....	0.093	1
Fort Corcoran	....	....	0.087	1

Considering the methods of collection followed by Professor Remsen and myself as of about equal value, it appears that the outside air of Washington contains nearly the same average quantity of free ammonia as that of Baltimore, with a slight advantage in favor of the former (represented by the figures for K street, Table V); and that the air of the laboratory yard has generally contained rather more free ammonia than that of the neighboring street, for reasons already mentioned. At the time of taking the samples examined from the clerk's office of the Bureau of Medicine and Surgery there were no instruments at hand for taking the relative humidity, but it was observed that the air was notably dry and oppressive, the rooms being heated by steam-coils. Moisture being a necessary factor in the decomposition of organic matter, it is probable that the very small quantity of ammonia observed on that occasion was due to the dryness of the air, as well as to the fact that the apartment is large, occupied by but few persons, and kept unusually free from dust. The circumstances being exceptional, this observation has not been considered in the calculations of Table IV.

Albuminoid, or "potential" ammonia, is essentially different from free in its nature, representing the as yet undecomposed organic matter which is present in the air at the time of examination, and which is not by any means necessarily hurtful, although always open to suspicion. In this respect the hygienic importance of free and albuminoid ammonia in air and in potable waters differs decidedly. The atmospheric organic substances which afford ammonia after distillation from potassic hydrate and permanganate may be living or dead vegetable detritus not liable to decay under ordinary atmospheric conditions, or animal detritus (epithelium, for example), charged with the poison of infectious exanthemata. We have no chemical means of discriminating between hurtful and harmless organic matter, and are therefore compelled to regard all alike with suspicion. So far as free ammonia in itself is concerned, it is probable that no product of decomposition is more nearly innocuous, and that its importance to the hygienic chemist resides only in its value as an index to the amount of organic matter that has already undergone decomposition. In so far it occupies with more dignity the place about to be vacated by carbon dioxide.

In 16 observations in which albuminoid ammonia was estimated by atomization (see Table III) the least result was 0.024 milligram to the cubic meter, in K street, near the laboratory, April 28, 1881, and the greatest, 0.220 milligram, in the laboratory yard, January 27, 1881. The mean of the 16 observations is 0.121 milligram. The observations are compared with those made elsewhere, and separated according to the localities of collection in Tables VI and VII, which follow:

TABLE VI.—*Estimations of albuminoid ammonia in one cubic meter of external air.*

Observer.	Locality.	Maximum.	Minimum.	Mean.	No. of observations.	Mode of collection.
		Milligrams.	*Milligrams.*	*Milligrams.*		
*R. Angus Smith ..	London and vicinity....	0. 271	0. 085	0. 150	18	Air washed by shaking in bottle with water.
†R. Angus Smith ..	Laboratory and vicinity	0. 427	0. 095	0. 266	10	Do
*R. Angus Smith ..	London Underground Railway.	0. 457	0. 290	0. 373	2	Do.
*R. Angus Smith ..	Glasgow	0. 457	0. 258	0. 304	4	Do.
‡Ira Remsen.......	Baltimore..............	0. 457	0. 041	0. 182	11	Aspiration through pumice-stone.
J. H. Kidder	Washington	0. 220	0. 024	0. 121	16	Atomization of water with air.

*Air and Rain, pp. 436–438. †Many of these observations made indoors.
‡Report on Organic Matter in the Air, National Board of Health Bull., September 11, 1881, p. 520.

TABLE VII.—*Milligrams of albuminoid ammonia per cubic meter of air.*

(Washington observations.)

Locality.	Maximum.	Minimum.	Mean.	Number of observations.
Laboratory yard	0. 220	0. 060	0. 126	9
K street, near laboratory	0. 125	0. 024	0. 086	3
Smithsonian Institution	0. 216	0. 180	0. 198	2
Bureau Medicine and Surgery			0. 005?	1
Window of laboratory			0. 050	1
Fort Corcoran			0. 090	1

Disregarding, as in the case of free ammonia, the indoor observations of Mr. Angus Smith, and the observation made at the Bureau of Medicine and Surgery, an examination of the Tables VI and VII indicates that the air of Washington contains less undecomposed organic matter than that of the cities with which it is here compared. Several considerations tend *a priori* to the same conclusion, the streets being unusually wide, often interrupted by extensive parks, and in the neighborhood of the observations paved with smooth asphaltic concrete, which is unfavorable to the retention of dust. It occurs to me, however, that the process of collection by atomization, theoretically as nearly perfect as possible for free ammonia, may be open to criticism, when the solid parts of organic air dust are to be examined. For I have often noticed a remarkable tendency in air dust to *adhere* to surfaces, and it may be that some of the particles have been arrested in this way in the course of the tube leading from the hand-ball to the atomizer, although the orifice of the latter has not yet been observed to be obstructed from this cause. The number of observations in each case presented is too small, and the variations between maximum and minimum too wide, to admit of any claim that these figures represent the actual mean contents in ammonia or organic matter of the air examined, and such inferences as may be drawn from the observations must be qualified by the consideration that the composition of the air has been found to differ widely in places very near together, at about the same time, owing to local causes. The most that we can infer is that the quantity of free and albuminoid ammonia in the external air of Washington is not excessive in quantity, and compares favorably with that of other cities. It is reasonable also to suppose that the quantity usually ranges within the extremes here presented; that, where ventilation is free, the winter and summer air do not differ greatly in organic contents, and that the air of large and well-ventilated buildings need not be worse in this regard than that out of doors, even when artificially heated.

A few specimens of snow and rain water, and of moisture condensed from the air upon cold surfaces, have been examined for ammonia, with the results which follow:

December 27, 1880.—The last of a snow-fall was collected and Nesslerized without distillation; reaction for ammonia distinct, with normal color. The specimen amounted to less than 100 *c. c.*, and was therefore not estimated quantitatively. It was, however, distilled, the destillate giving a distinct *yellow* color with the Nessler reagent.

January 31, 1881.—A portion of the first of a snowfall, taken near the ground in the laboratory yard after several days of clear and dry weather, showed: Before distillation, 0.200 milligrams ammonia to the liter; after distillation, 0.470 milligrams ammonia to the liter; albuminoid, 0.084 milligrams ammonia to the liter; all of the normal color.

February 19, 1881.—A large quantity of rain, collected in a vessel exposed all night in the laboratory yard, showed: Before distillation, a trace of ammonia; after distillation, 0.0214 milligrams ammonia to the liter; albuminoid, 0.0530 milligrams ammonia to the liter.

February 27, 1881.—A small quantity of the first of a rainfall showed 0.5 milligrams ammonia to the liter before distillation. The specimen was not distilled.

March 8, 1881.—About 140 c. c. of the first of a shower, collected in the laboratory yard, showed: Before distillation, 0.500 milligrams ammonia to the liter; after distillation, 33.300 milligrams ammonia to the liter; albuminoid, 0.200 milligrams ammonia to the liter.

A comparison of this very large quantity of free ammonia with the specimen collected February 19, the latter representing the mixture of the later with the earlier parts of a rainfall, shows how very large a part of the free ammonia in the air is washed out by the first part of a shower. Lest the quantity noted March 8 should appear to be improbably large, I will mention that M. Bineau found the *average* contents of winter rain in ammonia (at the Lyons Observatory, 1853) to be 16.3 milligrams per liter. M. Boussingault found 50 milligrams to the liter of moisture condensed from a fog, and Mr. Angus Smith has noted to the liter of rain 14.7 milligrams, at Glasgow; 22.9, at Manchester; 32.35, in Bishopgate street, London; and 39.80 in another street in London. It is not noted as to any of these estimations that they were confined to the *first* of a rainfall.* The last-named observer supposes that ammonia in rain water is never free, but combined with hydrochloric or sulphuric acid. It is plain that such a specimen as that examined March 8, if presented for analysis as a potable water, would be promptly rejected on account of the excessive quantity of ammonia, both free and albuminoid, which it contains.† So far as the free ammonia is concerned, however, inasmuch as the gas has originated from the decomposition of organic matters not contained in the water itself, such a conclusion would probably be erroneous. As to the quantity of albuminoid ammonia, although it falls below the average

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*Air and Rain, pp. 277 *et seq.*

†Water Analysis, Wanklyn & Chapman, London, 1879, p. 68.

determined by Angus Smith for all Scotland,* excluding Glasgow (0.212 milligrams to the liter), I do not feel satisfied that it would be safe to disregard so large an indication, even for rain-water, although, in places where the supply of drinking-water comes entirely from rain (Gibraltar, for example), no hygienic objection has, to my knowledge, been urged against it.

Moisture has been frequently collected upon cold surfaces, as in the experiment first suggested by Moscati in 1809, and in a single instance enough was got to permit of Nesslerization. Two large glass funnels were securely stopped, washed on the outside with much tap water, but not wiped, slung securely, and filled within with pounded ice. When the relative humidity and temperature were not too low, moisture from the air was condensed on the outsides of the funnels in quantity sufficient to drop into clean wide-mouthed glass-stopped bottles, which had been thoroughly washed with boiling distilled water. Between April 22 and May 18, 1881, about 9 fluid ounces of moisture were collected in this way, the bottles being kept securely stopped when not in use, and examined for ammonia on the last-named date, with the following results: Before distillation, 0.15 milligrams ammonia to the liter; after distillation, 13.6 milligrams ammonia to the liter; albuminoid, 0.24 milligrams ammonia to the liter. The liquid was found to be feebly alkaline to litmus, the red color being restored on drying (free ammonia), and contained vibriones, bacteria, fungi, flagellate and ciliated infusoria, and unrecognized ova, besides an alga resembling *œdogonium*.

March 9 two specimens were examined which had been collected in the same way at intervals since February 9, one out of doors and the other within the laboratory. Owing to the coldness of the weather the quantity was small, and I note only that the free ammonia before distillation was very much greater in the outdoor specimen than in that taken indoors, and that the former presented a faintly alkaline reaction, with algæ and many quiescent organisms not noted in the latter. A specimen collected August 30, after only two hours' exposure at an open window 30 feet from the ground, contained "much free ammonia," and very little solid matter.

These experiments have, of course, no quantitative value, but are interesting as indicating that even in winter a considerable quantity of ammonia appeared in specimens taken out of doors; much more, indeed, than was found in those collected within the laboratory. It is probable that the source of the ammonia is to be sought rather in the organisms whose germs were carried down by the outdoor moisture, and which afterwards developed into life or decayed, than in the contents of the air at the time of collection.

As to other chemical ingredients of the air, which are supposed to be due to the decomposition of organic matters, viz, nitrates, nitrites, and, according to Angus Smith, sulphates (from the oxidation of sulphuretted hydrogen†), no attempt has been made in the course of these observations to get quantitative estimations. The *presence* of these salts has been observed occasionally, as follows:

In 11 atomizations, no nitric acid, nitrites once, sulphates twice.

In 2 snowfalls, nitric acid once, no nitrites, sulphates once.

In 3 rainfalls, nitric acid twice, nitrites twice, sulphates twice.

In 4 condensations, nitric acid once, nitrites 3 times, sulphates 4 times.

For nitric acid, brucia and the indigo tests were employed; for nitrites, starch and iodine; and for sulphates, baric chloride. Usually the liquid was concentrated to one-fourth its bulk before applying the tests.

Other substances were recognized as present in sufficient quantities to respond to chemical tests, as follows:

In 11 atomizations, chlorine was recognized 8 times, silicate of alumina 9 times, calcium once.

In 2 snowfalls, chlorine was recognized once, and silicate of alumina twice.

In 2 rainfalls, chlorine, calcium, iron, and aluminium silicate each once.

In 4 condensations, chlorine 4 times, calcium twice, sodium, potassium, and magnesium each once.

I do not mean to assert that these or other substances were not present in the air oftener than above stated. Many of the specimens were examined only for special substances; many others were not examined chemically at all; my examinations last year‡ having given me no reason to believe that the air of Washington was likely to contain salts not frequently observed in that of other places. Such chemical tests as were applied were made with a view to the identification of certain microscopic crystals which have appeared in drops of wash-water dried upon glass slips, and which will be referred to again in the course of this report, rather than to determine the absolute frequency and number of the substances sought for. It is probable that chlorine, sodium, potassium, calcium, carbon dioxide, and sulphuric acid are always present in the air, even when not in sufficient quantity to respond to the ordinary reagents applied to the small amounts of fluid examined.* Carbon dioxide, for example, which is known to be always present in the air, and supposed to be present in rather unusual quantity in the locality under consideration, was never recognized by chemical tests, and sodium chloride was often identified by its microscopic crystals when the quantity was too small to give a reaction with silver nitrate.

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* *Op. cit.*, p. 321.

† *Op. cit.*, p. 265.

‡ See Report of the Surgeon-General for 1879, p. 50.

MICROSCOPIC EXAMINATION OF THE AIR.

The material for the microscopic examination of the air has been obtained in the following different ways:

1. Evaporation to dryness of a drop of the fluids resulting from atomization and from condensation of moisture upon cold surfaces.
2. Air dust collected upon slides and small flattened watch-glass-like disks by simple exposure within and without doors.
3. Air dust collected and retained by a drop of glycerine upon glass slips exposed to the air.
4. Air dust collected by the contrivance represented by Fig. 3.

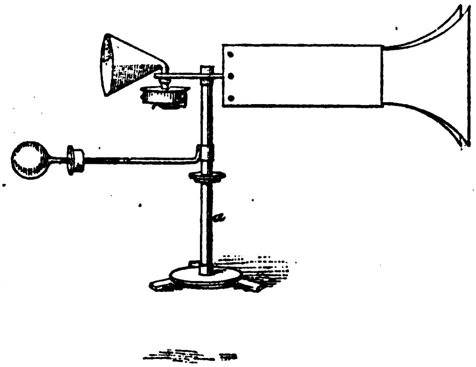

FIG. 3.

The contrivance consists essentially of a double-winged vane, turning freely upon an agate bearing, and carrying at the end opposed to the wind a glass funnel with its stem bent at right angles. Beneath the end of the funnel a glass slip, upon which is a drop of glycerine, is held horizontally by spring clips. A movable weight serves to balance the two ends of the vane, and the upright rod, *a*, can be unscrewed from the tripod and stuck into any wooden surface. For this purpose it terminates in a sharp steel point, not shown in the figure.

The principle of this apparatus is not essentially different from that of the aëroscopes devised by Pouchet,† Maddox, and Dr. Cunningham.‡ In these instruments the funnel has been drawn out to a fine point, so set as so impinge upon a thin cover or slip set vertically, and the glycerine with which the latter was covered had a tendency to absorb moisture from the air and to run off from the glass after long exposure. By bending the tube of the funnel at right angles this difficulty has been obviated in the apparatus here figured, and some improvement has been made in the details of its construction.

The photo-micrographs and drawings presented herewith illustrate the more frequently recurring and conspicuous microscopic objects observed in the specimens collected by the methods above described, with such explanatory notes as the short time at my disposal will allow. It is much to be regretted that the necessity for an immediate presentation of this report makes it impossible to discuss these numerous and varied objects as their interest deserves. I hope, however, that the illustrations will be sufficient in themselves to produce something of the pleasure which their long study has afforded myself, and that the investigations indicated will not prove to have been made altogether in vain.

Moisture which had been impregnated with the contents of the air, either by "atomization," condensation upon cold surfaces, or by the natural washing process of rain and snow falls, when dried upon a glass slip has been found to contain the following-named substances:

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* See Air and Rain, p. 233; Parkes' Hygiene, 5th ed., p. 102; Les Poussières de l'Air, Tissandier, Paris, 1877, p. 12, &c.

† *Comptes rendus*, T. 1, p. 748.

‡ Microscopic Examination of Air, D. D. Cunningham, surgeon, &c., London, 1874.

1. Epithelium from the skin and mucous membranes.
2. Vegetable epithelium and unrecognized débris.
3. Hairs and threads of various fabrics.
4. Particles of sand, glass, metals, soot, and starch.
5. Parts of the chitinous shells of small insects.
6. Bits of feathers and the pappus bristles of composite plants.
7. Minute, highly-refracting dots, simulating *micrococcus*.
8. Crystals of various forms and sizes.
9. Pollen spores of many different kinds.
10. Leaf hairs.
11. Mycelium and spores of fungi.
12. Nucleated cells, resembling leucocytes.
13. Bacteria, as *bacterium*, *vibrio*, *bacillus*, and *micrococcus*, and under the forms of aggregation known as *zoöglœa*, "swarms," *leptothrix*, and *torula*.

When observed fresh, after preservation for a longer or shorter time in well-stopped glass bottles, the same moisture has contained, besides many of the objects above noted—

1. Living algæ.
2. Amœba, flagellate and ciliate infusoria.
3. Fungi.
4. Bacteria of many forms.

Specimens collected by the vane aëroscope (Fig. 3) and mounted in glycerine, abounded in pollen, leaf hairs, spores of *sphœria*, epithelium, and detritus, both organic and inorganic.

Dust collected dry, by simple exposure of slips and disks to the air, contained sand, soot, &c., and numerous crystals, mostly rods and radiating needles.

And, finally, the disks and tubes containing collections made in hospital wards abounded in epithelium, starch, cells resembling leucocytes, and threads and hairs.

Epithelium, as appears from the foregoing summary, is always and everywhere present in the air. The specimen from which the accompanying illustration (photograph No. 126) was taken was collected out of doors on the 4th of February by atomization when the temperature was below freezing. Considering the probability of the communication of contagious exanthemata by this mode, the constant presence of epithelium in the air becomes a fact of considerable hygienic importance.

Particles of *glass* are often found upon air-slides which do not come from the air itself, but from the tube by which the drop to be examined is transferred to the slide, and which is often allowed to rest upon the slide for a time, while the solid contents of the drop are subsiding. When the glass tubes used for this purpose have been heated to incipient fusion, so that the sharp edges of their orifices are rounded, no particles of glass appear in the specimens.

Entire shells of *acarini* (No. 92) have been not uncommon in the air. Other insect detritus have been mostly scales of lepidoptera and parts of flies and spiders.

The pappus bristles of many of the *compositœ*, especially the late flowering asters, are often found in the air; a common form resembles miniature stems of *equisetum*.

Minute, highly-refracting dots, very numerous in winter dust, are likely to be mistaken for *micrococcus*, especially when mounted in fluid and agitated by the Brunonian movement. They are usually the most minute parts of coal-ashes, and may be distinguished from organic forms by the fact that they are not affected by strong sulphuric acid. The accompanying specimen was separated by Surgeon J. M. Flint from the dust of a room provided with a coal fire, by elutriation. Upon chemical examination the dust was found to consist almost entirely of *aluminium silicate*, a product of the combustion of coal. In old slides minute drops of moisture are very likely to collect upon the under surface of the covering glass, presenting much the appearance of *micrococcus*. A gentle heat will usually cause such dots to disappear.

As noted in my report of last year,* microscopic crystals are of common occurrence in residues of moisture which has been exposed to the air, and present a great variety of forms. I have spent a great deal of time in efforts to identify these crystals by comparing them with the forms presented by artificial solutions of the chemical compounds found by actual analysis to be present in the air. In this way it has been possible to recognize with reasonable certainty crystals of sodium chloride, sulphate and bicarbonate, ammonium chloride, sulphate and carbonate, potassium sulphate and carbonate, and calcium sulphate. Some of the most common forms remain, however, unidentified, including a great variety of acicular crystals, grouped in radiating bundles, which I presume to be fat acids and their salts, resulting from the decomposition of organic matter and the evaporation of perspiration. In photograph No. 71, for example, such a crystal appears to have been caught in the act of formation from a scale of epithelium, and a conspicuous bundle appears in the dried drop of perspiration represented by No. 89.

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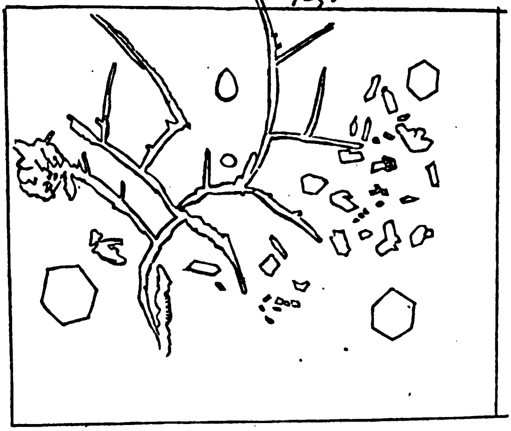
* Report of the Surgeon-General, 1879, p. 51.

After a long series of observations I am, however, constrained to believe that there is no absolute reliance to be placed upon identity or similarity of form in the recognition of crystals occurring in dilute solutions. The accompanying rough sketch (Fig. 4), for example, reresents some of the different forms observed in the residue from a single drop of a dilute solution of Merck's "C. P." potassium carbonate in distilled water. If all of the forms there represented are actually the same salt, it is evident that they are too much influenced by the circumstances under which crystallization is effected to be relied upon for identification. The hexagons, I may remark in passing, have always been found in residues from potassium carbonate, and are of frequent occurrence upon air-slides.* The accompanying photographs (Nos. 20, 61, 66, 68, 95, 122, 123, 124, 135, 139, 140, 142, 143, 153, 154, 157, 158, 160) are so labeled as to the date, source, and nature of the specimens represented, so far as this last may be ventured upon, as to furnish all necessary explanation. No. 50, from an artificial solution of calcium butyrate, is introduced to show the tendency of the salts of fatty acids to take on the radiating forms observed in some of the illustrations presented.

Fig. 4



Potassium Carbonate, from dilute Solution × 145

The curious pollen of the pine (Nos. 149, 156), and the leaf hairs represented by Nos. 26, 91, 145, are among the commonest objects in the air of early spring. Later in the season the place of these forms is taken by other kinds of pollen (Nos. 141, 146, 147, 150, 155), among which those of several species of grass (mostly species of *Poa* and *Agrostis*) have been recognized. The form illustrated by photgraph No. 167 is of especial interest, in that it was observed to be present in great numbers in the nasal secretion of a case of *catarrhus æstivus*, in August last. It resembles the pollen of a grass, and was first noticed in the air August 19.

Fungi which have been noticed are represented by photographs Nos. 51, 57, 65, 70, 74, 157. Most of these doubtless have been developed *in situ*, after the slides had been prepared. In early summer the peculiar spores of *Sphæria* (*herbarum?*) (photograph No. 51) were of common occurrence. This fungus has been found growing upon the

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*In *Les Poussières de l'Air* (Paris, 1877), M. Gaston Tissandier has figured many varieties of crystals, obtained for the most part from snow and rain (pp. 24–25), which he describes as nitrate of ammonia. This is scarcely possible, since similar crystals have often been observed during the past year in residues from moisture which was found to contain no trace of nitric acid. He confesses, moreover (p. 27), that he has tried in vain to reproduce the forms figured by evaporation of solutions of this salt, which is, in fact, far too deliquescent in its nature to persist at ordinary humidities. From repetitions of his experiments I conclude that only the slender needles figured on page 24 of his work can possibly be ammonium nitrate. Most of the forms shown in that and succeeding figures can be reproduced by the crystallization of sodium chloride (cubes), potassium carbonate (hexagons), ammonium chloride (crystals branching at right angles, or angles of 45°), ammonium sulphate ("*glaives*"), calcium sulphate (rods obliquely cut at the ends), sodium sulphate (sheaf-like forms), and ammonium carbonate (fan-like rows of dots). All of the forms figured by Tissandier have been observed in specimens collected from the air of Washington.

minuter stems of red clover in the laboratory yard (No. 51). Fungi are always present in moisture condensed upon cold surfaces, within a few days of collection. Thes specimens (of condensed moisture), although closely stopped, have been found likewise to contain living *algæ*, *amœbæ*, flagellate and ciliate infusoria, and *bacteria* o many forms (see Nos. 133, 136, 137, 158, 159, 160), the spores or germs of which mus have been present in the air, even when collected in winter.

Nucleated cells resembling leucocytes, are generally the dry and quiescent form o ciliated monads. It may be, however, that in air from hospital wards they ar really pus cells, but the actual presence of monads in the air, under a form closel simulating pus cells, should be borne in mind when such air dust is under examination.

Finally, photographs Nos. 65, 70, 76, 88, 151 represent forms of doubtful nature, deposited from the air, or formed upon slides in presence of the air.

EXPLANATION OF PLATES.

PLATE 1.

Negative No. 20. Crystals, salts of fat acids and potassium sulphate, from in-door air-dust. × 300.

Negative No. 61. Crystals, salts of fat acids, from air-dust of bedroom. × 260.

PLATE 2.

Negative No. 71. Fat crystal forming from a scale of epithelium. Air-dust of laboratory. × 260.

Negative No. 89. Residue from a drop of perspiration, dried on a glass slip. × 245.

PLATE 3.

Negative No. 122. Crystals from moisture condensed from out-door air. × 290.

Negative No. 50. Crystals of calcium butyrate from dilute artificial solution. × 260.

PLATE 4.

Negative No. 57. Fungus (*Phycomyces nitens?*) from air-dust of bedroom. × 260.

Negative No. 74. Mucor and bacteria (?) from moisture condensed from out-door air. × 260.

PLATE 5.

Negative No. 137. Bacteria and crystals, from moisture condensed from out-door air. × 670.

Negative No. 88. Crystals (?) and bacteria, from a very dilute solution of sodium chloride, exposed to the air. × 130. (The larger round spots are drops of moisture condensed on the under surface of the covering glass, and a little within the focus.)

PLATE 6.

Negative No. 157. Crystals, mycelium of a minute fungus, bacili, micrococci and nucleated cells (ova?) from moisture condensed from out-door air. × 300.

Negative No. 65. From air-dust of bedroom. × 260.

PLATE 7.

Negative No. 145. Leaf-hairs and pine pollen from out-door air dust. × 300.

PLATE 8.

Negative No. 150. Nucleated cells, residue from a drop of melted snow. × 300.

Negative No. 160. Nucleated cell and crystalline needles from moisture condensed from air. × 300.

PLATE 9.

Negative No. 126. Epithelium from out-door air, by atomization. The black dots are aluminium silicate. × 290.

Negative No. 154. Crystals, bacilli and micrococci (?) from moisture condensed from out-door air. Some of the small dots are partly deliquesced crystals. × 300.

PLATE 10.

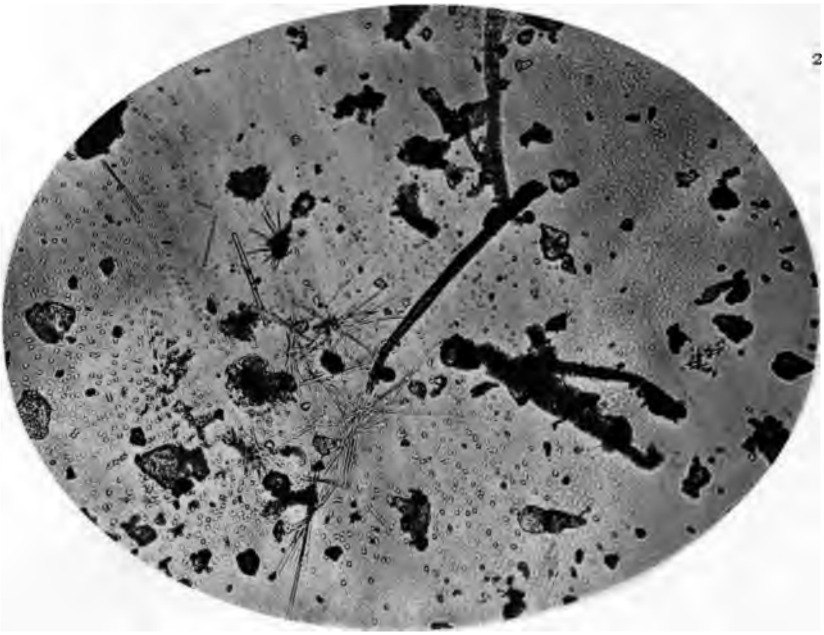
Negative No. 170. Compound spore of *Sphæria* (*herbarum?*) from out-door air dust. × 300.

Negative No. 167. Spore of a pollen, common in the air dust of late summer, and found in large quantity in the secretions of "hay-fever." × 300.

INDEX TO NEGATIVES.

Negative No. 20	Plate 1	Negative No. 126	Plate 9
No. 50	Plate 3	No. 137	Plate 5
No. 57	Plate 4	No. 145	Plate 7
No. 61	Plate 1	No. 150	Plate 8
No. 65	Plate 6	No. 154	Plate 9
No. 71	Plate 2	No. 157	Plate 6
No. 74	Plate 4	No. 160	Plate 8
No. 88	Plate 5	No. 167	Plate 10
No. 89	Plate 2	No. 170	Plate 10
No. 122	Plate 3		

PLATE 1.



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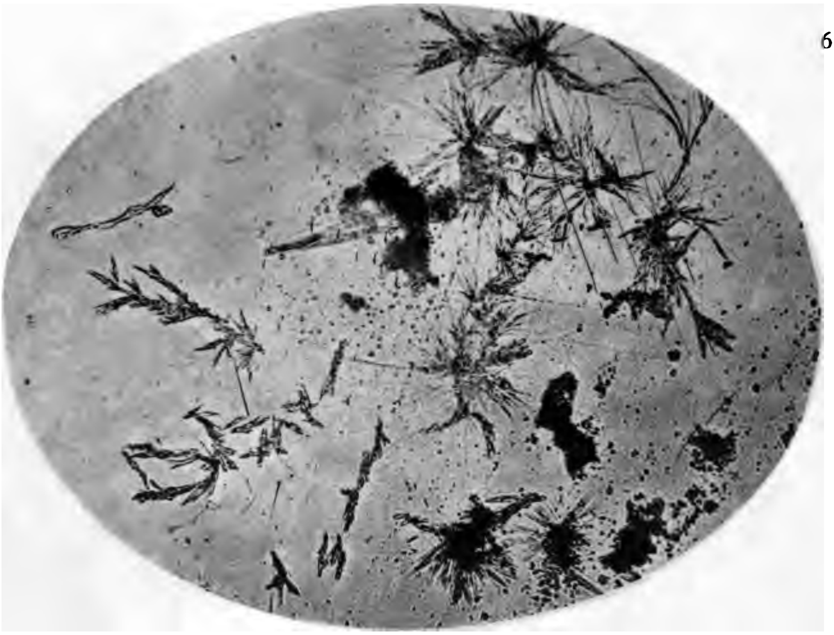

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Phototype, F. Gutekunst, Philada.

PLATE 2.

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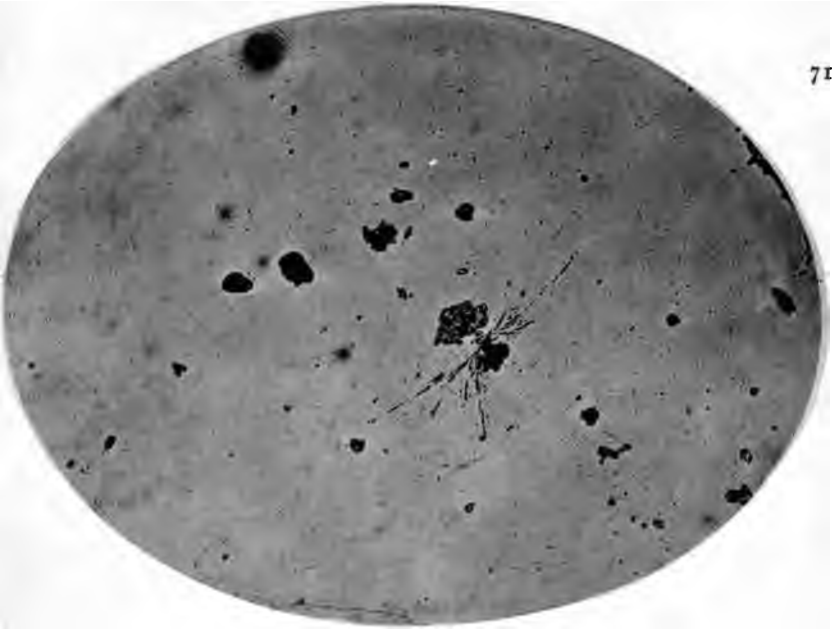

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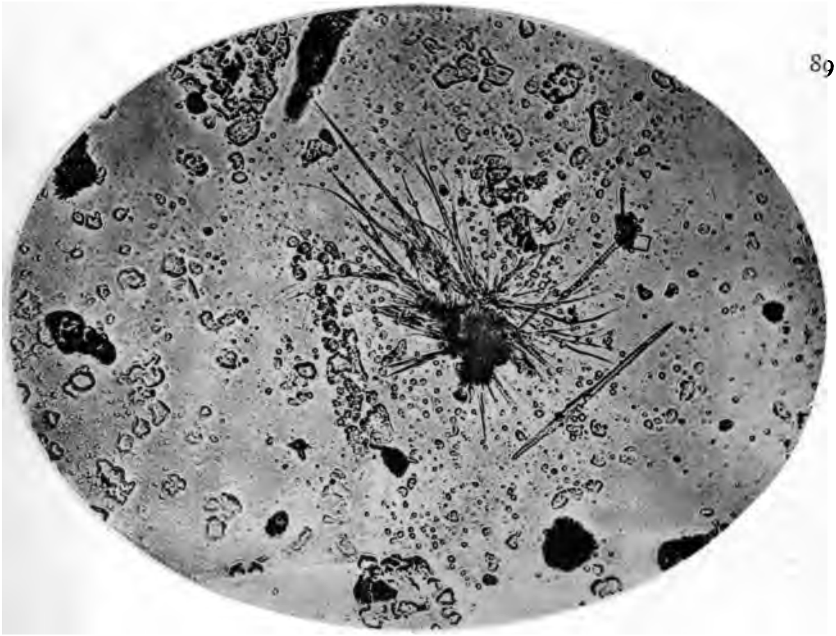
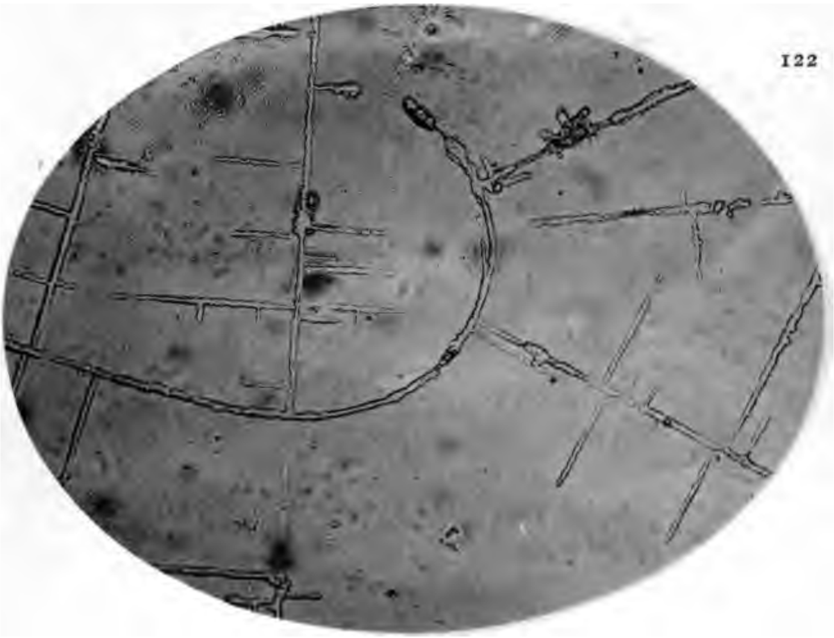


Phototype, F. Gutekunst, Philada.

PLATE 3.



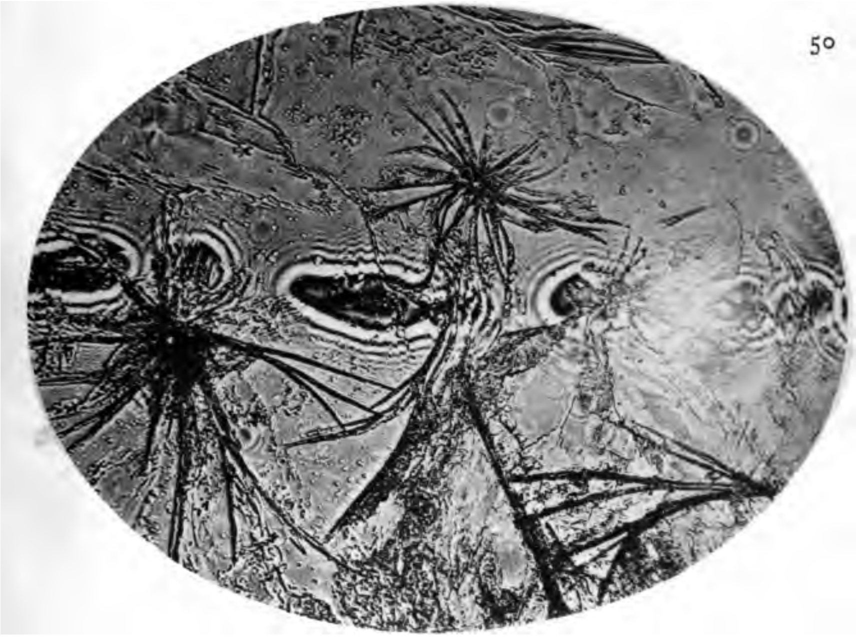


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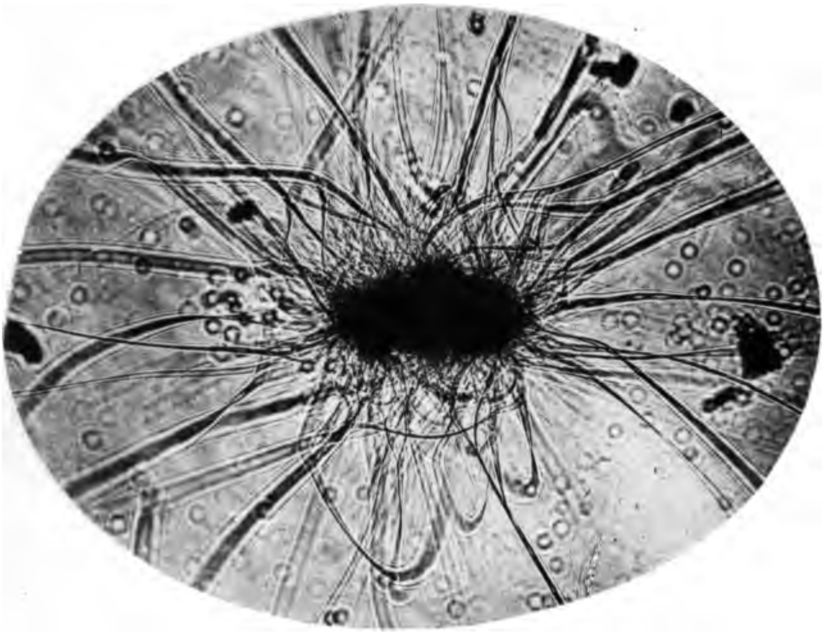
PLATE 4.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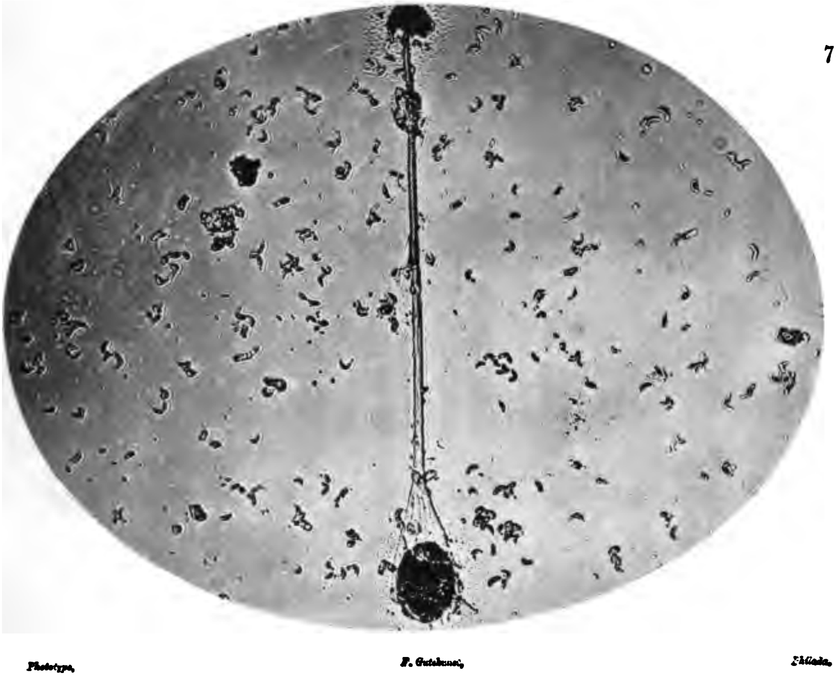
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Phototype, F. Gutekunst, Philada.

PLATE 5.

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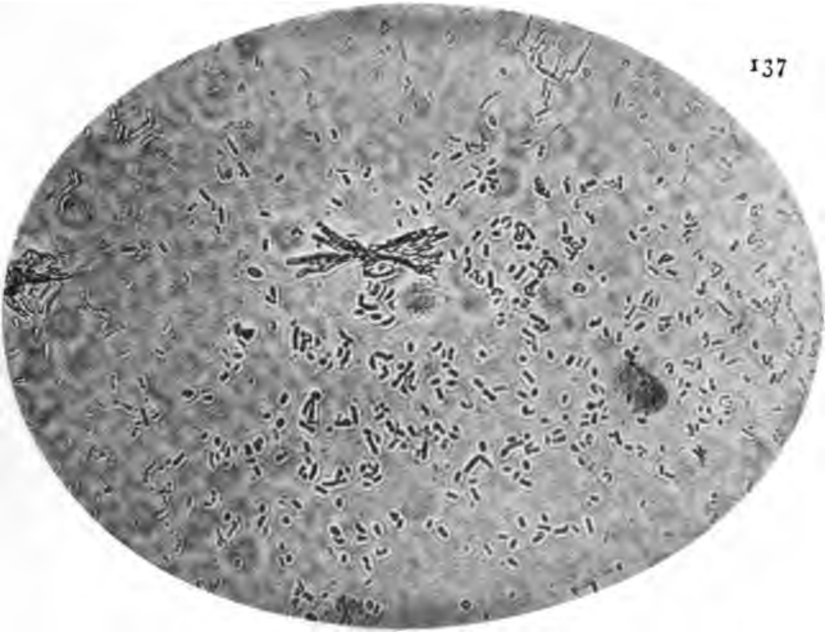

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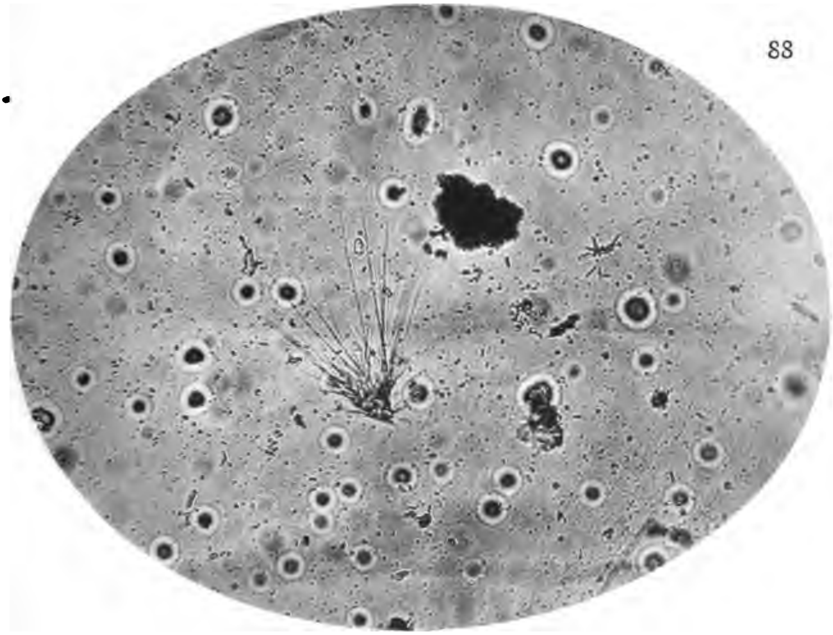

Phototype, F. Gutekunst, Philada.

PLATE 6.

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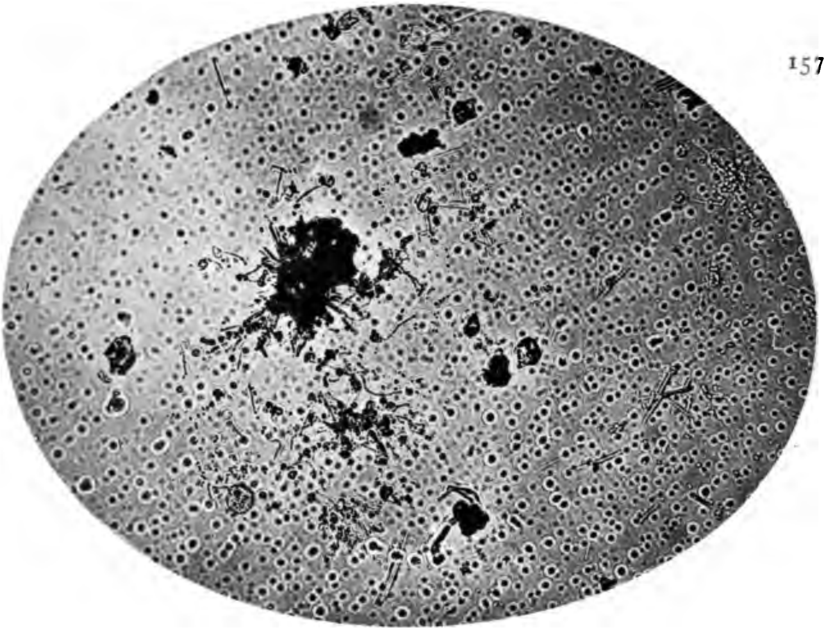

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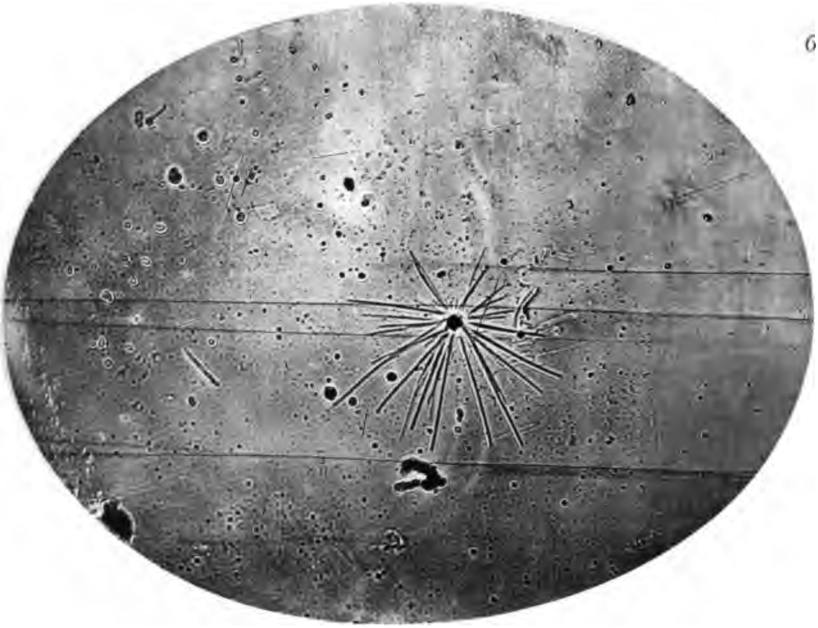

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PLATE 7.

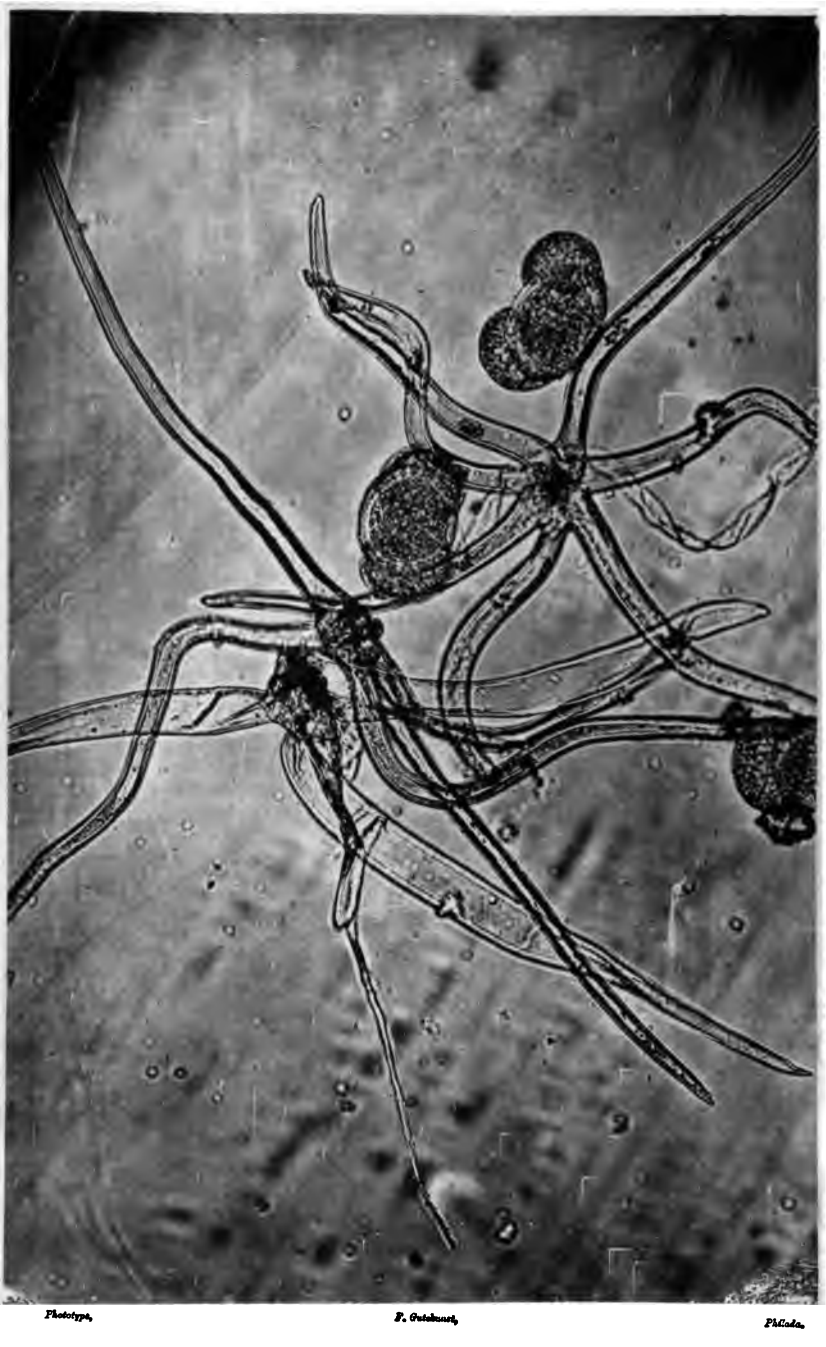

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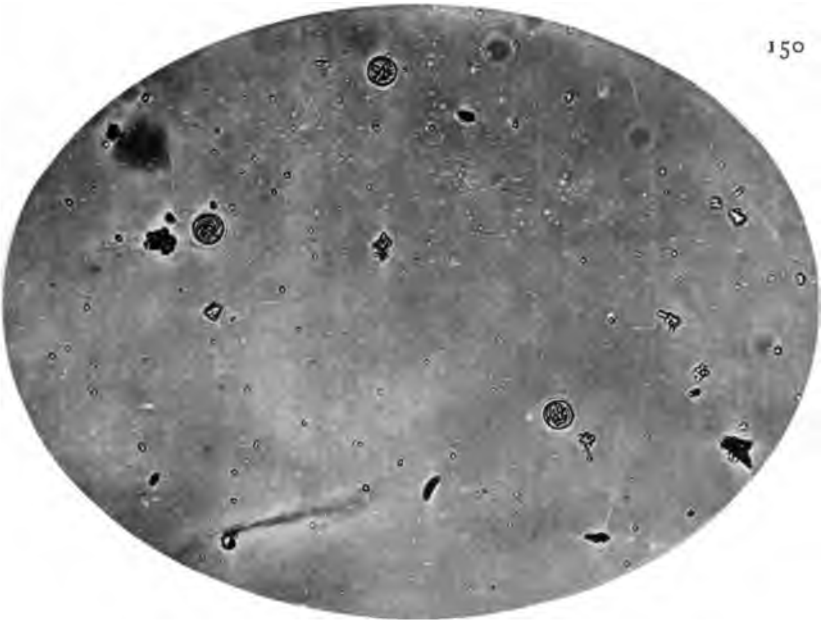
PLATE 8.



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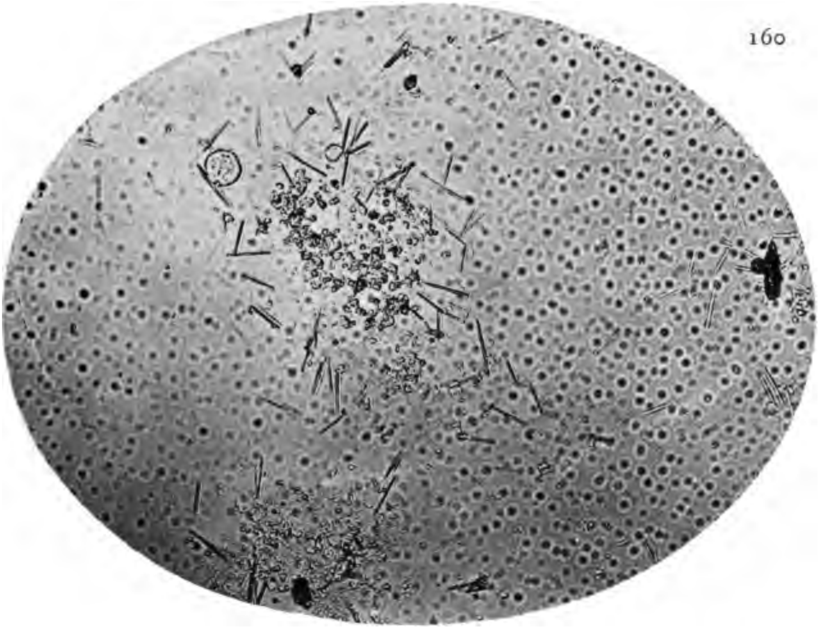

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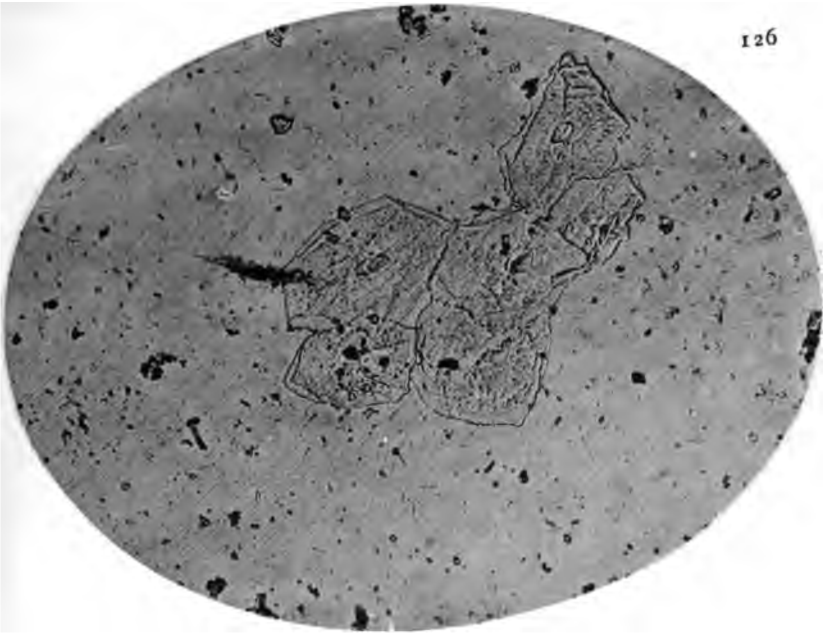
Phototype, *F. Gutekunst,* *Philada.*



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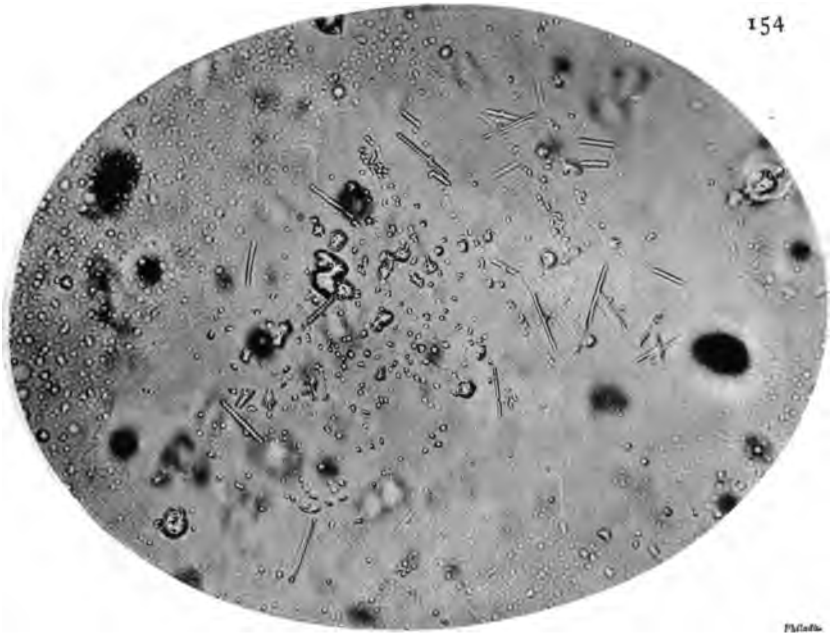

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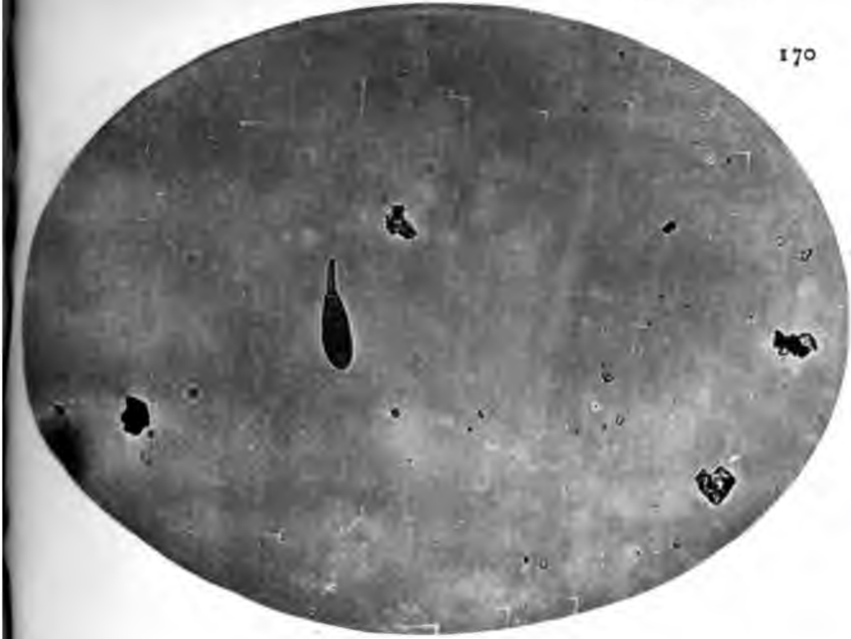
Philada.

F. Gutekunst,

Phototype.

PLATE 10.



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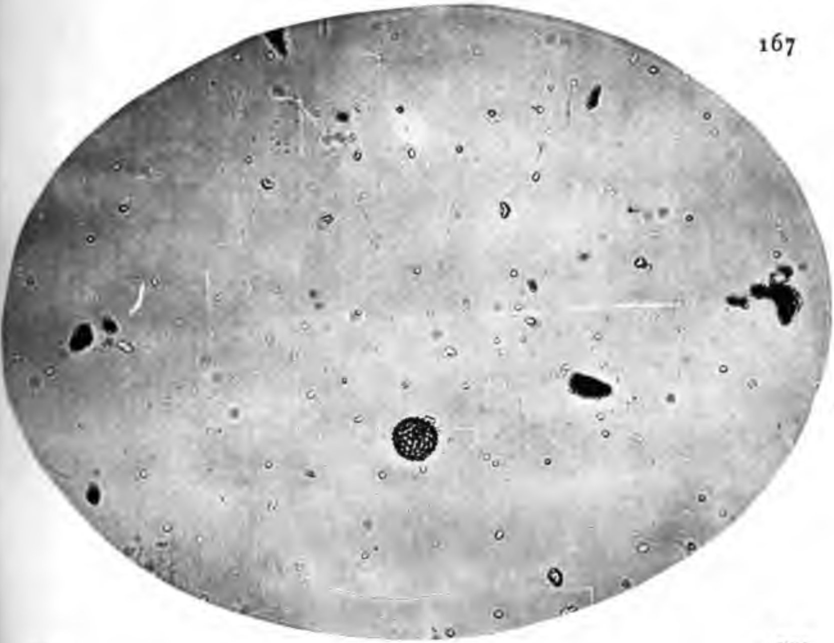

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Phototype, F. Gutekunst, Phila.